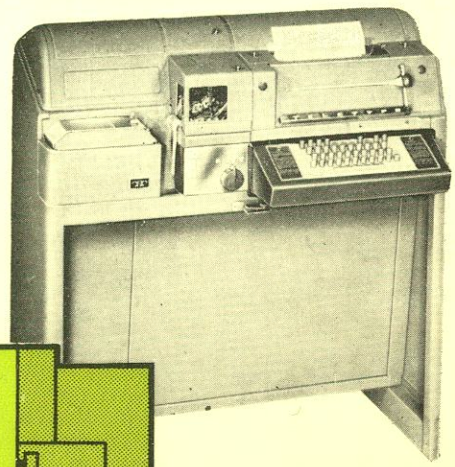
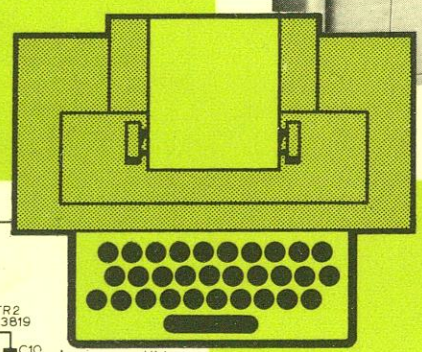
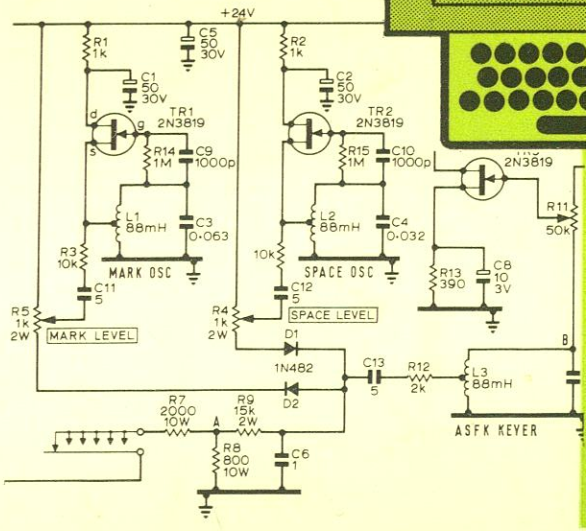
teleprinter handbook

AN RSGB PUBLICATION







This volume covers the theory and practice of modern radio teleprinter equipment, both European and American. In addition to full descriptions and maintenance data of all popular machines the Handbook fully covers the design and use of ancillary equipment. Although the theory is covered, this is not only a book for the library, but also for the engineer's desk and the workbench. For all who use, design or service teleprinter equipment this volume will be invaluable.

UK PRICE

£5.00

Christmas 1973.

THE TELEPRINTER HANDBOOK

THE TELEPRINTER HANDBOOK

First Edition

BY
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35 DOUGHTY STREET, LONDON WC1N 2AE

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First Edition

Printed in Great Britain for the Radio Society of Great Britain, 35 Doughty Street, London WC1N 2AE
by The Garden City Press Limited, Letchworth, Hertfordshire SG6 1JS

THE TELEPRINTER HANDBOOK

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Acknowledgment is gratefully made to ITT Creed Ltd., of Hollingbury, Brighton, for much information about Creed teleprinters in general, to Siemens AG of Munich for information on the Siemens T100 teleprinter, to The Teletype Corporation for permission to reproduce information about the Teletype Model 28 (copyright 1966) and the Model 15 (copyright 1944), and to Associated Automation Ltd., of Willesden, London, N.W.10, The Plessey Company Ltd., of Poole, Dorset, Signetics Inc., the Telephone Manufacturing Co. Ltd. (Components Division) of Canterbury, Data Publications Ltd., Ham Radio Inc., and *The RTTY Journal* for much useful information and assistance.

In addition, acknowledgment is made to the following individual radio amateurs for advice and help generously given:

R. W. Addie, G8LT
J. Baldwin, G3UHK
P. Balestrini, G3BPT
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FOREWORD

THE first *RTTY Manual* was produced in the early sixties by Dr Arthur Gee, G2UK, the then Secretary of the British Amateur Radio Teleprinter Group. It was a slim handbook of 85 pages but provided a wealth of information for the small band of amateurs who were by then beginning to be interested in the new mode of communication on the amateur bands. Now over a decade later, this, its successor, sponsored by the RSGB, has been compiled with the same aim in mind, namely to gather together in one volume all the accumulated information that has grown up in the intervening years.

Within its pages will be found chapters devoted to all aspects of rtty communication including those describing equipment which can be constructed as well as information on the very large selection of printers, tape equipment terminal units and test gear that has become available on the surplus market.

Special attention has been focused on machines that are of European, as distinct from American, origin although the latter are included for completeness.

A careful study of the book will enable the intending rtty enthusiast to acquire the basic knowledge that is necessary to understand the principles of machine telegraphy, but it sets out all the steps that the newcomer will have to take to enable him both to receive and send rtty, which in itself opens up an entirely new mode of operation.

Unlike most of the other modes in use today which have become so well developed that the newcomer can, if he wishes, simply go and purchase his gear and get going, the rtty man has perforce to gain more than a basic understanding of the principles involved in the new sphere of activity. It is the combination of the electronic skills that he will have used in other ways with the newer electro-mechanical problems that surely make radio teleprinter work an absorbing pastime. There is much scope for ingenuity in the use of the different machines and their build-up into a full and easily controlled station system. The maintenance and rebuilding of these provides a good, if at times frustrating, way of getting to understand them and for which the *Handbook* provides considerable help.

In the early days of rtty it was sufficient to get a working printer and terminal unit and most of the pioneering work was done with relatively simple gear. As the art developed, however, the capabilities increased and as other countries found teleprinter machines becoming available there was real incentive to look for long distance contacts. This in turn encouraged better terminal units with much narrower filters, circuits to discriminate against unwanted signals and noise and the ability to operate as an unattended "autostart" system. Gradually 850Hz shift, which was the norm, is being replaced by 170Hz which, while posing new technical problems of filters and stability, is enabling good copy to be exchanged in conditions that approach the marginal even for cw. At the time of going to press the FCC have authorized USA amateurs to use speeds higher than the 45·5 bauds to which they have so far been tied and no doubt speeds of 100 bauds will come into use. Bearing in mind that by the use of tape gear rtty makes maximum use of the channel it may be said that it is one of the less selfish forms of communication in these days of crowded bands and unwanted noises of all kinds.

Finally, no handbook would be complete without the help unstintingly given by the manufacturers of equipment and their permission to use material and pictures from the various manuals and publications; also by the editors of a number of journals, both British and USA, devoted to amateur radio and rtty in particular. Acknowledgments will be found in these pages.

THE BRITISH AMATEUR RADIO TELEPRINTER GROUP

THE British Amateur Radio Teleprinter Group is affiliated to the Radio Society of Great Britain and exists to further the knowledge and practice of rtty in amateur circles.

With small beginnings in 1959 the group has steadily grown until it now has over 250 members from 16 countries. This handbook has been compiled mainly by members of this group who together have many years of practical experience of rtty in all its forms. Regular newsletters are circulated and it provides a ready pool of information on the subject, which varies from the problems confronting members to advice on the purchase and selection of equipment. The committee sponsors an annual world-wide rtty contest as well as more recently a vhf contest which have both created considerable interest. There is a regular liaison with similar groups in other European countries as well as the USA and Canada. Membership is available for a modest subscription and comprises almost all those in the British Isles who have an active interest in rtty.

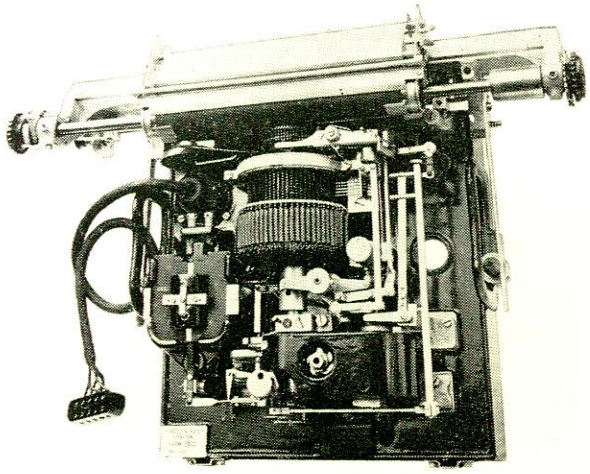
HISTORY

IT was in 1837 that Sir Charles Wheatstone with William Fothergill Cooke invented the first practical telegraph system, known as the Five Needle System. In this system, a combination of five needles was made to point to the letter signalled. As this method required five signalling wires and was difficult to use, it was soon replaced with a double needle system and then a single needle system operating on Morse code, invented by Samuel F. B. Morse in 1844.

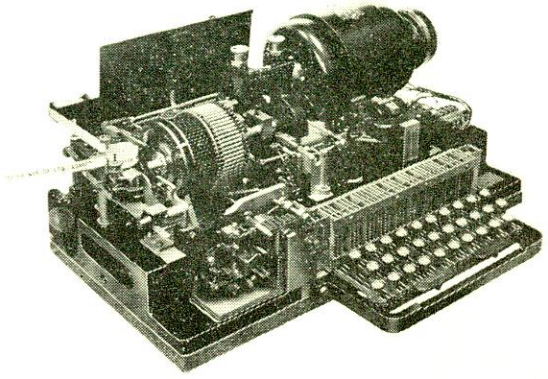
During the following decades, many ideas were put forward, many experiments tried with varying degrees of success, and in 1874 a Frenchman, Emile Baudot, of the French Telegraph Service, worked out a system of printing telegraphy using a five-unit selecting code which is still in use and is known as the Baudot code.

The main feature of the ideas which had been tried up until the turn of the century was that they required two skilled operators to send and receive a message, and that there was no directly printed copy. It was not until 1902 that two Americans, Jay Morton and Charles L. Krum, demonstrated a practical machine capable of direct printing a message on a paper tape. In 1907, Morton and Krum formed a company, the Morkrum Company, later to become the Teletype Co, with a capital of $150,000.

At about this time a telegraph operator with the Central and South American Telegraph and Cable Company in Peru thought out an idea that would enable complete Morse code signals to be punched in a tape by operating the keys of a typewriter-style machine instead of the slow and laborious "stick" perforator method then in use. This operator was F. G. Creed and he left his job and set sail for Britain, determined to put this and other ideas into practice. After early disappointments he developed a compressed air driven keyboard Morse tape perforator for which the GPO ordered 12 machines in 1902.



The Creed model 2P teleprinter



The Creed model 3 tape teleprinter

Creed and his mechanics then produced two further machines, a receiving Morse perforator, and a printer which accepted the received message tape and decoded it into plain language printed characters on ordinary paper tape.

Thus was born the Creed High Speed Automatic Printing Telegraphy System, and in 1908 the company of Creed, Bille and Company Limited was incorporated. It was known as Creed, Bille, as at that time Mr Creed was working in association with Harald Bille, a well-known Danish telegraph engineer who was killed in a railway accident in 1916. After his death, his name was dropped from the company title.

In the USA at this time, a German-born immigrant, Edward Kleinschmidt, made a teleprinter that showed he was both an electrical and mechanical genius. Kleinschmidt's Company and the Morkrum Company carried on their separate ways until 1925 when they combined, and were taken over by the American Telephone and Telegraph Company in 1930. Since then, patents have run out, and a new Kleinschmidt Company has been formed.

It was in 1924 that the teleprinter really began to come into its own. A Morkrum Teletype machine arrived in England, operating on the now familiar five-unit start-stop telegraph code and was a direct printer, that is it recorded messages directly from the incoming line signals instead of from tape via a reperforator as in the Creed system. Here

was a real challenge, and Creed and Co lost no time in meeting it.

The result was the introduction of a separate keyboard transmitter and a receiving page printer, both operating on the five-unit start-stop teleprinter code. Orders for these machines were received from the Central News Agency in London, from the Exchange Telegraph Company, the British United Press and others.

The first printer, the Model 1P was soon superseded by the improved Model 2P, a machine which gave excellent service up until quite recent times. This marked the start of Creed's business in the teleprinter field, and practically all subsequent development work had to do with five-unit systems. Meanwhile, Donald Murray, a New Zealand farmer turned journalist, had invented the Murray Multiplex System—another five-unit code system—which had become popular in India, Australia, New Zealand, Brazil and Russia. Murray made a valuable contribution to telegraphy by rationalizing the allocation of the combinations of the five-unit code to the characters of the alphabet on a frequency-of-occurrence basis. His arrangement of the code in which the most frequently used letters of the alphabet are represented by the smallest number of holes in the tape, has since become standard practice.

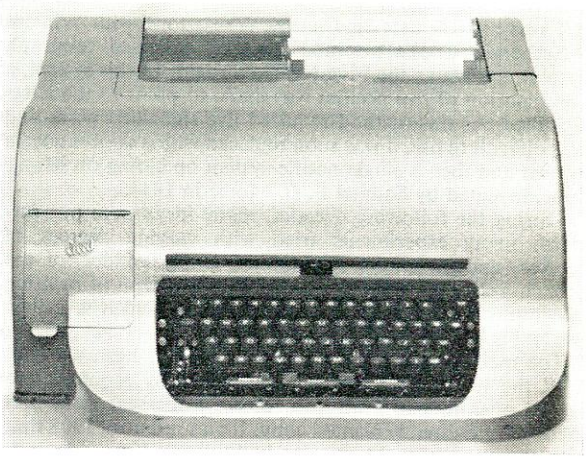
Murray's Multiplex System and other telegraph patents were acquired by Creed in 1925 and these machines were produced at Croydon for many years.

In 1927, the GPO introduced the public telegram service, and Creed and Co manufactured their first combined start-stop transmitter-receiver, the Model 3 Tape Teleprinter, for this service. Creed and Co was there to stay.

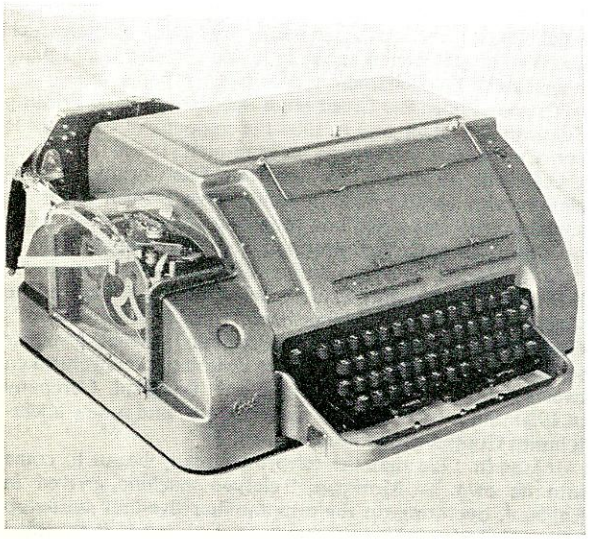
Over the years, Creeds have produced thousands of machines of many types, notably the model 7 and its variants, the model 47, a tape printer, produced in 1947, and the model 54, a page printer, produced in 1954. In 1958, the first production model 75 machines were shipped from Creed's Croydon factory.

It was realized in the 1960s that the models 7B, 7E and 54 used for the GPO telex service had reached the limit of development and so a new machine was designed, the 444. This machine, also known as the GPO model 15, is now being put into service.

The leading manufacturers of teleprinters and asosciated equipment are now: in America the Teletype Corporation, the Mite Corporation and the Kleinschmidt Company; in England, ITT Creed Ltd; in Germany, Siemens and Halske, and Lorenz; and in Italy, Olivetti,



The Creed model 54 page teleprinter



The Creed model 47 tape teleprinter (Illustration by courtesy of ITT Creed Limited)

The Creed model 75 teleprinter with tape reperforator

CHAPTER 1

ASPECTS OF SIGNALLING

MARK AND SPACE

MOST amateurs know that a "space" condition results in Morse code when the key is up, and when the key is pressed down, a "mark" condition results. In normal cw transmission of Morse, a space is simply carrier switched off and a mark is carrier switched on. This is known as on-off keying. The terms become more obscure when applied to frequency shift keying (fsk), for the transmitter radiates full power in both mark and space conditions. In this case the difference between mark and space is represented by a small change in carrier frequency.

It should be noted that in some applications, the mark is also known variously as 1, Z or Hi and the space as 0, A or Lo, but throughout this book will be called mark or space.

The Baud

The baud is the shortest single signal unit in a signalling code and may be expressed as the reciprocal of the time of the shortest signal element. If, for example, the shortest signal element were 20 milliseconds in length, then the telegraph speed would be $1/0{\cdot}02 = 50$ bauds. It is rather more precise than the term "bit" used by computer engineers, since it assumes a square-shaped signal which may be either a mark or space at a definite repetition speed. If telegraph signals were sent as "reversals", ie mark-space-mark-space alternately, one could define speed in terms of frequency, one mark followed by one space representing one complete cycle of a square waveform. The Murray code, however, has no gaps between the signal unit, and the mark-space sequence depends on the character transmitted. Letter A, for example, consists of two marks followed by three spaces in sequence, so that the waveform is not symmetrical, and cannot be described in terms of frequency without giving a totally incorrect impression of signalling speed, see **Fig 1.1**. Nevertheless, it is true to say that the highest signalling speed that may arise in any given code is the reversals frequency, which is 25Hz in the case of 50 bauds, and design of circuit constants must take this frequency into account.

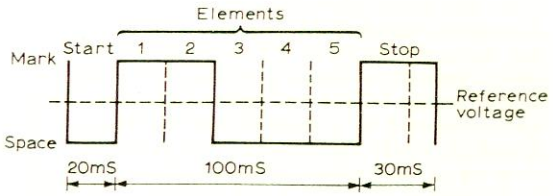


Fig 1.1. Letter A, typical character construction.

Speed stated in bauds is precise, and the length of the baud as a fraction of a second is implicit. Speed stated in words per minute is approximate only, since an average length word must be assumed.

In Morse code the number of bauds in a character varies greatly. The Morse baud is one dot. Letter E is thus equivalent to four bauds, the dot and the space of three dots' duration following before the next character commences. Figure 0 is 22 bauds, consisting of five dashes each worth three bauds, four spaces each worth one baud between the dashes, and the space of three bauds' duration following the character.

Murray code, used with teleprinters, always has five character bauds plus one start baud and one and a half stop bauds, the latter being used for machine synchronizing. All characters thus take the same time to transmit—an essential requirement for any form of type printing telegraph machine.

Murray Code

This is the five-unit code internationally adopted for teleprinting machinery. The complete code is shown in **Table 1.1**, and it will be noted that there are 32 possible combinations, of which 31 are used. The exception is the character comprising all spaces. A teleprinter receiving a continuous space condition is receiving a permanent start signal and will have its mechanism permanently rotating without printing any character. This condition is known as "spacing-in" and is commonly the first intimation that the telegraph line has become faulty.

The 32 combinations are derived from the fact that there are five code elements and each element has a possible two states. Therefore, the combinations $= 2^5 = 32$.

The 32 possible combinations available from the five-unit code are not sufficient for practical use, as there are 26 combinations required for the alphabet, leaving insufficient for numerals let alone punctuation. The solution is to use the code twice, that is to make a given combination print either a letter or a number. Two of the 32 combinations are used as shift signals, the function of which is to operate a mechanical change-over device on the teleprinter and so allow the mechanism to print either letters or numbers and punctuation only. The shift signals are also known as case-shift signals. One case is letter shift and the other is figure shift.

The marks and spaces which convey intelligence are

known as "elements" and are numbered 1 to 5 in sequence. When transmitted, the elements are also bauds, but the term element implicitly describes one of the bauds making up the character and not the start and stop signals, which are for synchronism and do not contain message intelligence.

The start signal is transmitted at the commencement of each character formation and finally a stop signal of one and a half bauds mark minimum duration is transmitted. When sending by keyboard the actual length of the stop signal will depend on how long the operator takes between pressing one key and the next. There is a locking bar on the keyboard which prevents the operator from pressing another key before the previous character has been fully transmitted, and this ensures that the length of the stop signal is at least one and a half bauds.

At a speed of 50 bauds the length of one baud is 20ms, so that each character takes 150ms to transmit. This is approximately equal to 66 words per minute.

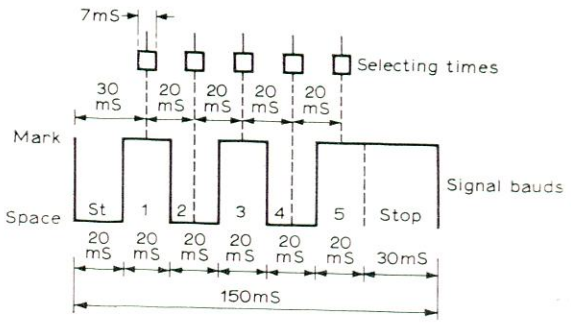


Fig 1.2. Letter Y showing ideal selector timing.

Start-stop Synchronizing

When a teleprinter is switched on, but the keyboard is at rest, it transmits a steady mark. If it is connected to a distant teleprinter receiving magnet, that magnet remains operated to mark and nothing happens. Both motors are turning, ideally at exactly the same speed, but the teleprinter mechanisms are idle because of a clutch device which isolates them from their motors. When an operator presses a character key he engages the sending mechanism and a start signal of one space baud is transmitted, followed by the five elements of the character and a stop signal. The start signal switches the distant teleprinter magnet to space and the clutch engages, causing the receiving mechanism to rotate. A mechanical selecting device then samples the position of the receive magnet armature at fixed intervals of time following the engagement of the clutch, **Fig 1.2**. After one rotation the clutch again latches during the period of the stop signal.

The intervals at which the selecting device looks at the armature position are determined by the speed of rotation of the mechanism. The first "look" is timed to take place about the middle of the first character element. Thereafter the "looks" are spaced at 20ms intervals if the motor speed is absolutely accurate. Obviously, if either the transmit or receive teleprinter motor speed is inaccurate the "looks" will be displaced from the middle of the elements, and this is cumulative. If the receive teleprinter motor were running 10 per cent slow, the middle of the selecting "look" normally timed to take place 30ms from the commencement of the start signal would be delayed by 3ms. At the 110ms point from the commencement of the start signal, properly coincident with the middle of the fifth element, the middle of the selecting "look" would be displaced by 11ms. Since the element length is only 20ms and the "look" takes a finite time (about 7ms in old type teleprinters), the need for accurate synchronism is important. In practice one teleprinter motor may be running slightly fast and the other running slightly slow. The speed differences add, so that the maximum speed error that could possibly be allowed, assuming no distortion of baud length arising from any other source, would be equal to half the displacement of the fifth element selection to the start or finish of the fifth element baud. The baud length is 20ms and the selection time is 7ms disposed equally about the baud at its 10ms point. This leaves 6·5ms of the baud either side of the selection period. Only half this displacement can be allowed and this works out to about 2·7 per cent deviation of motor speed. However, although two teleprinters, one having its motor running 2·7 per cent fast and the other 2·7 per cent slow, connected by a piece of wire introducing no signal distortion, would theoretically print correctly, in practice there are so many sources of possible baud length distortion or mechanical bias that a much more realistic figure for motor speed accuracy is plus or minus 1 per cent. The motor governor can achieve this accuracy.

TABLE 1.1

The Murray Code.
Upper case characters may vary.

Upper Case	Lower Case	Elements 1	2	3	4	5
-	A	M	M	S	S	S
?	B	M	S	S	M	M
:	C	S	M	M	M	S
AB†	D	M	S	S	M	S
3	E	M	S	S	S	S
%	F	M	S	M	M	S
@	G	S	M	S	M	M
£	H	S	S	M	S	M
8	I	S	M	M	S	S
Bell	J	M	M	S	M	S
(	K	M	M	M	M	S
)	L	S	M	S	S	M
.	M	S	S	M	M	M
,	N	S	S	M	M	S
9	O	S	S	S	M	M
0	P	S	M	M	S	M
1	Q	M	M	M	S	M
4	R	S	M	S	M	S
!	S	M	S	M	S	S
5	T	S	S	S	S	M
7	U	M	M	M	S	S
=	V	S	M	M	M	M
2	W	M	M	S	S	M
/	X	M	S	M	M	M
6	Y	M	S	M	S	M
+	Z	M	S	S	S	M
Carriage Return		S	S	S	M	S
Line Feed		S	M	S	S	S
Word Space		S	S	M	S	S
Letter Shift		M	M	M	M	M
Figure Shift		M	M	S	M	M
All Blank		S	S	S	S	S

† AB denotes the key which triggers an answer-back mechanism which can be fitted to the distant machine.

A speed fault can be diagnosed fairly easily by analysis of the page-printed copy at the receiving end and reference to the Murray code. It will be noted that, as the teleprinters start in synchronism by reason of the start signal, and then run slowly out of synchronism because of the difference in motor speeds, it is always the fifth element that is most likely to be incorrectly recorded because of displaced selection. If, therefore, the text of the message contains a number of errors all of which show incorrect sensing of the fifth elements, but which show correct sensing of the earlier elements, the trouble is almost certainly speed, but the fault could be on either the transmit or receive teleprinter.

Speed

The term speed when used in connection with printing telegraphy usually means the number of words per minute that the equipment can handle. A word is defined as five characters plus a character space. Creed machines operating at 50 bauds generate 7½ units of 20ms length = 150ms. Therefore a word = 6 × 150ms = 0·90s length. Because there are 60 seconds in a minute, a machine operating at 7½ unit 50 bauds can send or receive 60/0·90 = 66·6 words per minute.

Western Union characters at 7·0 units of 22ms are 154ms long. Therefore a Western Union word is 6 × 154ms = 0·924s long. Consequently, this results in a send/receive rate of 60/0·924 = 65 words per minute.

Bell System keyboards produce characters of 7·42 units of 22ms length. The speed, therefore, will be 7·42 × 22ms = 163ms per letter, and 60/6 × 163 = 61·3 words per minute.

Fig 1.3. A simple telegraph system.

Fig 1.4. Double current telegraph system.

PRINCIPLES OF TELEGRAPH SIGNALLING

The object of a telegraph system is to transmit a signal from one point and to receive it at another point. For this purpose, the signal is conveyed in the form of a code of signal elements, and consideration of how these elements are formed and recognized will now be given.

Fig 1.3 shows a simple telegraph system in which pressing the key causes a current to flow and so deflect the galvanometer needle at the distant station. When the key is up no current flows, so the two conditions in this system are "current" and "no current". Therefore, there would be two corresponding galvanometer needle positions and thus signalling could be accomplished by means of a code in which different groups of needle movements represent different characters. Alternatively, a sounder or buzzer may be connected in place of the galvanometer, so producing an audible signal. Such a circuit, in which current flows in one direction only, is known as single current or neutral keying.

The circuit in **Fig 1.4** is similar to that in **Fig 1.3** except that when the key is not pressed an opposite polarity current to that flowing when the key is pressed is present. This method of operation is known as double current or polar keying and is almost universally used in Great Britain by the Post Office for the Telex service.

On a teleprinter, pressing a key causes a moving contact in the transmitter to switch between two fixed contacts, at a rate and sequence dependent upon the telegraph speed (45·5 or 50 bauds, etc) and the letter selected. If the fixed contacts have a positive and a negative potential applied to them, the resultant output, taken from the moving contact, will be a double-current signal. However, if only one fixed contact has a potential applied the output will be a single-current signal.

The receiving line of a teleprinter circuit is connected through a current-limiting resistor to an electromagnet whose armature movement initiates the mechanical functions of the teleprinter. Obviously, since all elements are transmitted sequentially with no pauses between them, the magnet must operate and release very quickly and follow the marks and spaces faithfully. There must be a finite time during which the armature is in motion. The machine is interested in only two conditions—mark and space, which is armature fully operated or fully released. The time taken for the armature to travel from one condition to the other is known as the "transit time". If this time is an appreciable portion of the baud length it will reduce the time available for the selecting mechanism of the teleprinter to determine the polarity of each baud. This becomes very serious when working over a radio path, because considerable distortion of baud lengths can be fortuitously introduced by ionospheric phenomena, such as multiple path propagation. Moreover, the time taken for the armature to move from mark to space must be the same as that taken to move from space to mark, or a mechanical bias of the mechanism will result.

A machine using single-current signalling has an electromagnet whose armature is returned to space by a spring. When the magnet is energized the magnetic force acting on the armature has a square law characteristic. The nearer the armature gets to the pole face the greater the magnetic force acting upon it. Thus, to travel from space to mark the armature can be in continuous acceleration. When the current in the magnet coil is removed, the spring, which has a linear characteristic, is left to return the armature to space

position. Its acceleration is therefore quite different. However, during armature operation by energizing the coil, the spring is acting against the magnetic force and a fairly delicate balance of spring tension against magnet coil ampere/turns can be found which makes operate and release transit times equal, at the expense of reduction of magnet sensitivity. It should be noted that the single-current Teletype machine requires 60mA magnet current against the 20mA used for Creed double-current teleprinters.

The double-current-operated machine employs a polarized electromagnet which is exactly balanced mechanically. As in the case of the simple headphone, polarization much increases the sensitivity of the magnet. It operates under exactly the same force conditions in both directions, since the armature is driven by magnetic force from space to mark and from mark to space. Consequently it does not introduce any inherent mechanical bias and the transit time is kept very short by the high sensitivity of the magnet.

TIME CONSTANTS IN TELEGRAPH LOOPS

Series RC Circuits

When a series circuit composed of a resistance, R, a capacitance, C, and a dc source, V, are connected, a current $I = V/R$ flows at the instant of circuit closure. As time progresses, the current slowly decreases until it reaches 0. The decay of current is governed by the product of R and C, and the current decays to 36·8 per cent of its initial value in a period of time in seconds equal to the product of R in ohms and C in farads. The voltage across the resistor follows this pattern; it starts at V volts at the time of circuit closure, decreases to 0·368V in RC seconds, and ultimately reaches 0V. The voltage across the capacitor starts at 0V, reaches (1 – 0·368) V = 0·632V in RC seconds, and finally reaches V volts.

If, after the capacitor has charged to V volts, the battery is disconnected, the capacitor will remain charged indefinitely. When the circuit is closed with the battery removed the capacitor will discharge and will reach 0·368V in RC seconds.

Series RL Circuits

In the case of a series RL circuit there are some similarities and some differences from the RC situation.

Consider the circuit shown in **Fig 1.5**, for the time being ignoring any similarity between this circuit and that of a telegraph loop. The circuit consists of a source of dc voltage, E, a switch, S, an inductor, L, and a resistor, R.

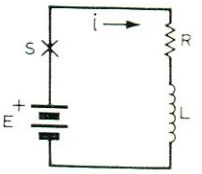
Assume the switch is open and no current is flowing. When the switch is closed the current, i, will start flowing and it will slowly increase as shown in **Fig 1.6**. The mathematical form of the current as a function of time is given by:

$$i = I\,(1 - \exp\,(-\,Rt/L)),$$

where 1 is the ultimate value of current and equals E/R, R is the total circuit resistance in ohms, L is the inductance in henrys and t is the time after switch closing in seconds.

The shape of the curve is such that it is essentially impossible to say when the current finally levels off to its ultimate value 1. Therefore, it is convenient to determine a point on the curve that can be specified mathematically and measured

Fig 1.5. Series RL circuit.



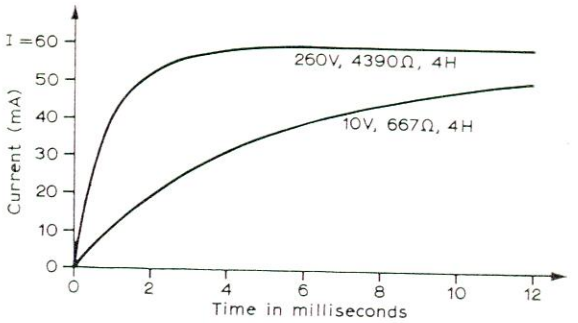


Fig 1.6. Current behaviour, using different voltages in the series RL circuit.

easily on an oscilloscope. This point is the place where the current has reached 63·2 per cent of its ultimate value 1. The current reaches 0·6321 when $Rt/L = 1·0$. Therefore, L/R is called a time constant; when the time after switch closure, t, in seconds equals the time constant, L/R, the current has reached 63·2 per cent of its ultimate value 1.

As an example take the following situations:

Assume that E = 260V, R = 4330Ω, and L = 4H. E/R = 60mA, therefore the ultimate value of current, 1, will be 60mA. The time constant, L/R = 4/4330 = 0·923ms. This means that 0·923 ms after the switch is closed the current will equal 0·632 × 60mA = 38mA.

As a second example, assume that E = 40V, R = 667Ω, and L = 4H. The ultimate value of current, I = 40/667 = 60mA, the same value as in the previous example. However, the time constant, L/R = 4/667ms. Therefore, even though both circuits will have the same ultimate current value, the second circuit requires more than six times as long for the current to rise.

Both of the above examples could apply directly to a telegraph-receiving loop. The switch, S, is the output or keyer valve or transistor in a TU (or metallic contacts on a keyboard or a relay), R is the total loop resistance, L is the inductance of the selector magnets, and E is the loop power supply.

The "moral" of the story to this point is that although both circuits will supply the 60mA required during a marking condition, the circuit with the low supply voltage possesses a long time constant (delay in current build-up); because the elements in a 66-speed telegraph signal are only 20ms long, the 6ms required for the current to build up to 63 per cent of 60mA is too long.

A similarity between RL and RC circuits is that they both

have time constants; a difference is that the RC circuit time constant is proportional to R while the RL circuit time constant is inversely proportional to R. Another difference becomes evident when the switch is opened. In the RC circuit, as noted above, the capacitor can remain charged indefinitely; after the switch is opened, the voltage across the capacitor will remain at V volts until something is done to the circuit. In the RL circuit the inductor can remain "charged" only so long as the current remains at 1A, and this requires that the circuit remains closed. As soon as the circuit is opened the inductor will "discharge". The "discharge" of the inductor, regardless of the circuit configuration, must obey the rule that the current through the inductor cannot change instantaneously. This leads to two interesting situations:

1. Assume that the circuit is as described previously: a simple series combination of an inductor, a resistor, a switch, and a battery. Assume that the switch has been closed for a while and a steady current flowing. If the switch is opened current must cease, but the inductor will not permit it to cease instantaneously. Therefore, as the switch contacts separate the inductor will react by generating a "back emf" of sufficient magnitude to break down the air gap between the contacts for a sufficient period to allow the discharge of the inductor; the air-gap breakdown is evidenced by a spark. This sparking will, of course, eventually damage the contacts. A remedy is to provide some alternate path for the inductor discharge current. A device providing this path is known as a contact protection (CP) network.

2. Assume the circuit is the same as described previously, but in addition a CP network composed of a series RC circuit is placed across the contacts. (The mathematical analysis of this arrangement can become involved unless certain assumptions regarding component sizes are made; we will assume the appropriate values.) Because the CP network is across the switch contacts it will have no effect upon circuit operation when the switch is closed; the closed or mark interval time constant will be L/R, where R is the loop resistance. When the switch is open the total resistance of the circuit will be the sum of the loop resistance and the CP network resistance; call this total resistance, r. Therefore the open-switch or space interval time constant will be L/r. The spacing or "turn-off" condition resistance, r, is larger than the marking or "turn-on" condition resistance, R; consequently, the current decay at switch opening will be faster than the current build-up at switch closure.

There appears to be a common misconception about the method of driving the selector magnets in a teleprinter.

Probably the main reason that selectors are put into unsatisfactory loops is the close resemblance of selectors and ordinary-type relays. A run-of-the-mill relay has a coil voltage rating. Therefore, it is logical to expect that the selector magnets in a teleprinter should also have some voltage rating and so long as that voltage is applied the teleprinter will function properly. ABSOLUTELY NOT!

Selector magnets have a current rating. They should be supplied from a current source, not a voltage source. Unfortunately a real, live current source is nonexistent. However, a current source can be simulated by using a relatively high voltage in series with a resistance. (The higher the voltage source and resistance, the closer will be the simulation.) The following will show how to do this and what happens if it isn't done.

AN INDUCTANCE-FREE LOOP

In order to provide a point of reference we will consider first a loop containing no energy-storage elements, ie no inductance or capacitance. **Fig 1.7a** shows such an idealized loop composed of some dc source, E, a resistor, R, and a switch, S. The voltage source and the resistor can be any value desired so long as their ratio permits a current, I = E/R, of 60mA to flow when the switch is closed. The switch can be metallic contacts, a valve, or a transistor. (Note that at this point we are not particular about the total loop resistance of supply voltage so long as the loop current is 60mA. However, it will become apparent later that the source voltage and loop resistance are as important as the loop current.)

The switch is assumed to be driven in such a manner that it opens and closes at even intervals of 22ms each, corresponding to the element length of a "60-speed" RTTY Signal.

Bias distortion

Bias distortion or, as it is usually called, bias, is the measure of the unevenness in length of mark and space elements. Usually it is expressed as a percentage and can be calculated from the formula: per cent bias = 100(m-M)/M,

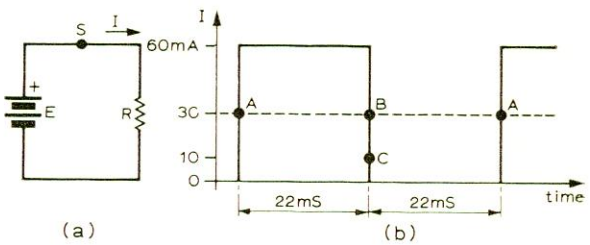


Fig 1.7. See text

where m is the actual length of a mark interval in units of time and M is the expected or normal length of a mark interval in the same time units.

For example, in **Fig 1.7b** the mark interval is supposed to be 22 ms long and it is shown as 22 ms long, therefore the per cent bias in **Fig 1.7b** is 100 × (22 − 22) /22 = 0 per cent.

In all examples to follow, the "ideal" mark will be 22ms long, therefore in all calculations M = 22ms.

RECEIVING DEVICES

In a receiving device such as the selector in a teleprinter there are essentially two conditions or states that the device can be in, the unoperated or spacing condition and the operated or marking condition. When no current is flowing in the magnets the armature will be unoperated or spacing. If current is slowly increased the armature will operate when the current reaches a certain value, called the operating current, and at that point the armature will make a space-to-

mark (S-M) transition; if the current is increased after the armature has operated no further action will take place. If the current is slowly decreased the armature will remain operated until a certain current value is reached, at which point the armature will release and a mark-to-space (M-S) transition will result. Once the armature has released, an additional decrease in current will cause no further action. The value of current at which the armature releases is called the release current.

The operate and release currents are dependent upon the immediate history of current within the device and upon the adjustment of the selector, especially the tension spring, if present, and the operated and non-operated air gap between the armature and the pole pieces of the magnets.

Because of the adjustment and history factors, the operate and release currents may be somewhat nebulous values. The operate current will always be more than the release current and may be several times as great. However, for illustrative purposes we will initially assume the two current values are equal, and equal to 30mA (half the normal loop current).

An Ideal Selector in a Simple Loop

Assume a selector could be built having no inductance in the magnets and having identical operate and release currents of 30mA. Place this "ideal" selector in the loop shown in **Fig 1.7a**. Because there is no inductance in the selector, the current would appear as shown in **Fig 1.7b**. The dotted line indicates the "operate-release" currents of this idealized selector. On a S-M transition in current the selector operates when the current goes through 30mA as indicated by point A. On a current M-S transition the selector releases when the current goes through 30mA as indicated by point B. (Point C will be considered later.)

Because the distance from point A to point B is 22ms the bias introduced into the selector is zero. (In this example m = 22ms, the distance from A to B.)

A Semi-ideal Selector

To progress one step towards a practical rather than ideal selector, assume the selector still has the same operate-release current levels of 30mA but that it has 4H inductance in the magnets. Insert this magnet into a simple series loop with contact protection as shown in **Fig 1.8a**. Note that the supply is a 130V source. R is the total loop resistance including the selector magnet resistance. S is assumed to be metallic contacts.

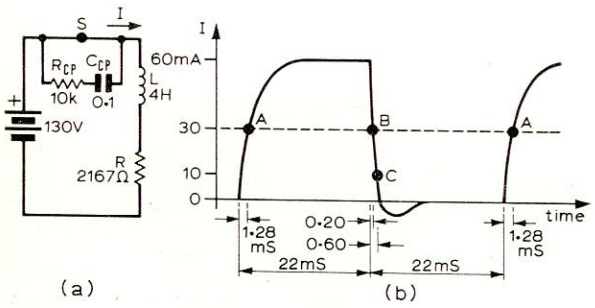


Fig 1.8. See text.

The loop current is shown in **Fig 1.8b**; because of the magnet inductance, L, it is no longer "square". In the S-M transition, the L/R time constant due to selector magnet inductance shows up and is approximately 1·84ms. In the M-S transition there is some overshoot resulting from the contact protection network composed of RCP and CCP. The time for the current to decay from 60mA to the point where it makes the axis crossing is approximately 0·66ms.

The operating point, A, is delayed by about 1·28ms because of the delay in current build-up due to the L/R time constant. Due to the L-R-C "time constant", the release point, B, is delayed by approximately 0·20ms. Therefore, bias is introduced into the selector as a result of sit own magnet inductance. In order to calculate the bias, m must be determined; m = 22·00 − 1·28 + 0·20 = 20·92-ms. Therefore, the bias is 100 (20·92 − 22·0) /22·0 = − 4·9 or 4·9 per cent spacing bias. This is not a bad value.

If a 260V source were used, R would be 4330Ω and the bias would be approximately 2·1 per cent spacing.

A "Triode" Switch

Metallic contacts may be considered archaic. Therefore, replace the contacts with a triode-like device such as a vacuum-pentode driven into hard conduction, a bipolar transistor driven into saturation, a unipolar transistor driven into the ohmic region, or a vacuum-triode. (It is tacitly assumed that the devices can be safely turned off rapidly.)

The only difference in current wave-shapes between the "triode" and metallic contact circuits would be a vertical drop in current during the M-S transition because no CP network is used. The bias would be 5·8 per cent and 2·9 per cent spacing for the 130V and 260V loops, respectively.

A "Pentode" Switch

A pentode vacuum-tube operated in a "constant-current" mode as a selector magnet driver presents a complex situation that requires quite a bit of reasoning to explain fully. Therefore, we will only describe the requirements for best operation and the resulting wave-shapes. (The term "pentode" is being used generically; it includes any device having a "pentode-like" characteristic. Bipolar and unipolar transistors when operated in a "constant-current" mode qualify but may not be practical because of their ratings.)

Consider the circuit shown in **Fig 1.9a**. The "switch" marked P is a pentode with the bias set to give 60mA loop current during a steady mark. The resistance in the loop including the selector magnet resistance and excluding the dc plate resistance of the pentode should be as low as possible. It may appear that a low loop resistance is contrary to what has been said about time constants; however, in this case it is indeed desirable. An explanation of why it is true with pentodes, and only pentodes, is lengthy and will be omitted.

During the S-M transition the current will rise linearly as shown in **Fig 1.9b**. The rise time (the time to go from 0 to 60mA) is dependent upon the supply voltage and the inductance, L, and not upon the loop resistance so long as the resistance is kept low. Note that the rise in current is linear rather than exponential as in all preceding and all

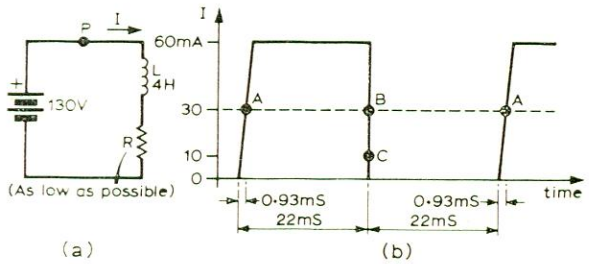


Fig 1.9. See text.

following examples. The rise time for a 130V source and L = 4H is 1·85ms, placing point A about 0·93ms delayed, and for a 260V source the rise time is about 0·92ms, delaying point A by 0·46ms.

During the M-S transition the resistance of the valve is nebulous, but is very high giving a very short time constant. Therefore point B will be undelayed. As a result, the bias will be 4·2 per cent spacing and 2·1 per cent spacing for the 130V and 260V cases, respectively.

Low-voltage Transistor Drivers

Fig 1.10a shows a loop consisting of a 12V supply and a "switch", X, which represents the C-E "junction" of a bi-polar transistor. In this circuit the total loop resistance, R, will probably be composed of only the winding resistance of the selector magnets. Because of parameter variation problems the transistor will probably have to be operated in the saturated mode. Therefore, the transistor will act very much like a switch. If this is true, the loop current wave-forms will appear as shown in **Fig 1.10 b**.

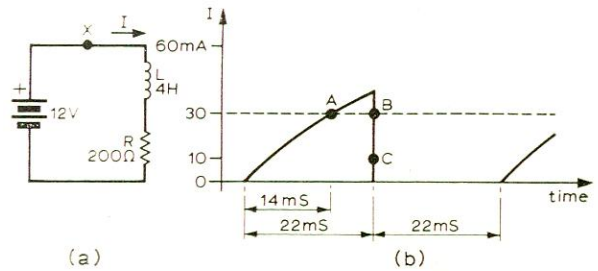


Fig 1.10. See text.

The time constant of the circuit, assuming 4 H inductance and 200Ω resistance, will be about 20ms. Therefore, even if the steady-state loop current is set to 60mA, the current rises so slowly that it never reaches steady-state during a typical mark interval. However, if three marks are sent in succession the current will reach 60mA by the end of the third mark. This is intolerable, and if it is ignored other problems will show up. (The situation in which steady-state current is not reached when rapid reversals are sent, such as in the letter "R", but steady-state is reached during the letter "M", results in characteristic distortion, a most undesirable situation.)

The operating point, A, has been shifted approximately 14ms. If the transistor can be safely turned off with no protection, the M-S transition will be as shown and the release point, B, will be in its normal position. Therefore, m = 22 − 14 = 8ms; the per cent bias = 100 (8–22) /22 = +63 or 63 per cent spacing bias! This is also intolerable.

The inductive kick occurring when the transistor is turned off may damage the transistor. This can be prevented by placing a diode in the circuit as shown in **Fig 1.11a**.

If we can assume that the diode when conducting has the same characteristics as the transistor when it is conducting, the wave-shapes will appear as shown in **Fig 1.11b**. Again, we have the problem of characteristic distortion resulting from the time constant being so long that steady-state is never reached when alternate marks and spaces are being

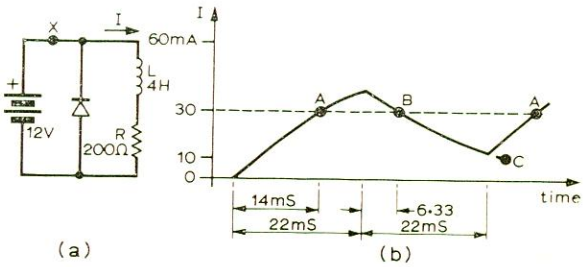


Fig 1.11. See text.

sent, but steady-state is reached when several marks or spaces are sent in succession. For this example the bias is 35 per cent spacing.

If the supply voltage is raised to, say, 36V, the loop resistance would be 600Ω and the time constant would decrease to 6·7ms. This is shown in **Fig 1.12**. Point A and point B are shifted about 4·7ms each so that no bias is present and the time constant is sufficiently short to allow steady-state conditions to be established by the end of each unit. (This circuit appears to be satisfactory, but when an actual selector is considered severe bias will exist.)

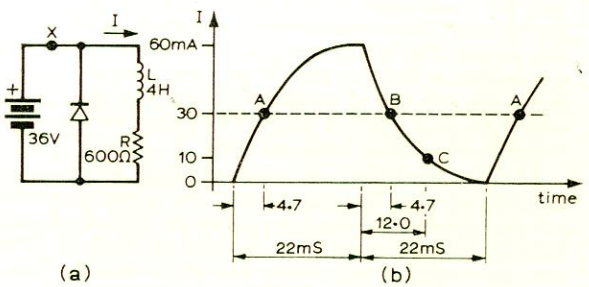


Fig 1.12. See text.

Operate and Release Currents

As mentioned earlier, the selector operate current has to be higher than the release current and may be several times as great. To illustrate this consideration we will repeat the whole discussion (in abbreviated form, thank goodness!). Let us assume the operate current is 30mA and the release current is 10mA. The point of operation, A, on all the diagrams will still apply, but the release point, B, will have to be replaced by point C.

In the simple contact-operated 130V dc loop shown in **Fig 1.8a**, the shifting of the release point from B to C will slightly decrease the bias because point C is delayed by about 0·6ms; the bias will be 3·1 per cent spacing. Using a 260V source gives 0·6 per cent spacing bias.

When using the "constant-current" pentode with a practical selector, the bias will be the same as it was with the "semi-ideal" selector, 4·2 per cent and 2·1 per cent spacing. Although points B and C are at different current levels, they are in the same time position because of the vertical nature of the M-S transition. This has a very important consequence: If the M-S and S-M transitions in the current supplied to the selector magnets are nearly vertical, ie have very short time constants or rise times, the operate and release current values will not in themselves affect selector operation. As a corollary, when rise times are long, selector operation is very dependent upon the selector operate and release current values.

In the case of the 12V loop with a transistor and diode, **Fig 1.11**, the selector magnets will never release the armature! This phenomenon may manifest itself in a subtle manner. Assume a solid-state TU having this type output circuit is being tested. With a steady mark at the input the output loop current is 60mA, with a steady space it is 0mA. When characters are sent the printer will copy infrequent-transition characters such as I, M, and O but will be unable to cope with frequent-transition characters such as J, R and Y.

The transistor and diode with a 36V source, **Fig 1.12**, although showing no bias previously, will now show A delayed by 4·7ms and C delayed by 12·0ms; this gives: m = 22 − 4·7 + 12·0 = 29·3ms. Therefore the bias is:
100 (29·3 − 22)/22 = +33·1 or 33·1 per cent marking bias!

Multiple Selector Magnets

If more than one selector is inserted into the loop, as in the case where a page-printer and a reperforator are being operated simultaneously, the circuit analysis can be made with little additional effort. Essentially, in all the previous examples the time constants would be doubled; the bias would also double. This means that a circuit that is marginal with one selector in the loop (say 33 per cent bias) will become inoperable with two in the circuit (66 per cent bias). However, if the bias is only 1 per cent initially, even four selectors will only result in 4 per cent bias.

As selector magnets are added the loop resistance will increase, lowering the loop current. The normal procedure for compensation is to employ a rheostat that is manually adjusted whenever a machine is added or removed. However, the change in loop current is smallest when the highest voltage source is employed. With a "constant-current" pentode no adjustment should be required.

Higher speeds

Although speeds higher than 66wpm are not presently permitted in amateur service, it might be desired to monitor higher-speed commercial stations. The time constants of a loop are not dependent upon the speed of operation, but the length of a unit interval is. With higher speeds the length of a mark (and space) are shorter making the time constant a larger fraction of a unit. This has the effect of increasing the bias as the speed is increased.

MISCELLANEOUS

The voltage appearing across the selector magnets has been totally ignored. Its magnitude is useless except as an indirect indication of the steady-state loop current flowing in the magnets.

Traditionally, polar relays were used for many reasons; two reasons are: (1) the operate and release currents are nearly equal, and (2) the inductance of the relay winding is relatively low.

Because of these two characteristics the relay will approach, closely, the "ideal" selector originally discussed and, as a result, will give better performance than a single selector in a poor loop as well as not additionally "fouling up" the loop by adding a lot of inductance.

USING A MILLIAMMETER IN A LOOP

A dc meter (voltmeter or milliammeter) is an average-reading device. This means that the indication given by the meter is the average (with time) of the current flowing through it.

If a very slowly alternating current is applied to a milliammeter, the meter will respond to the varying current and will, at any instant of time, give a reading corresponding to the current flowing at that instant of time. If a true alternating current were applied, half the time the meter would be going downscale because the current is reversed half the time and the deflection is directly proportional to the current flowing, including polarity.

The meter movement, although fairly lightweight, still has some mass and cannot, therefore, respond instantaneously. If the alternating current applied to the meter is increased in frequency, the meter may not be able to respond rapidly enough and the reading given by the meter will be less than it was previously even if the actual current being applied has the same magnitude. Remember, the higher the frequency, the faster the current (or voltage) varies with time.

If an even higher frequency alternating current is applied (50Hz is sufficient with most dc meters), the meter time to respond becomes so slow relative to the rate of variation of the ac that the meter will read zero. In other words, by the time the meter starts to respond upscale the applied dc has already reversed and it is trying to make the meter read downscale.

It is under this condition where the applied current is varying more rapidly than the meter can respond that the dc meter is truly average-reading. The average of a sine wave is zero, and that is what the dc meter reads so long as the meter "sluggishness" is sufficient to keep it from responding instantaneously.

A simple but typical single current telegraph loop is

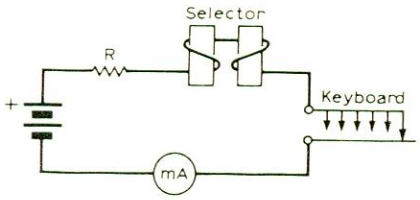


Fig 1.13. A basic telegraph loop.

shown in **Fig 1.13**. The loop consists of a power supply, some resistance, the selector magnets in the printer, the keyboard contacts and a dc milliammeter.

Assume for purposes of discussion that the dc milliammeter is 60mA full scale. Also assume that the selector in the teleprinter is a 60mA selector. Regardless of the loop supply voltage (which should be at least 130V dc), the resistor is to be adjusted to give 60mA loop current when the keyboard contacts are closed. (If the loop is keyed by a polar relay, a valve, or a transistor, the discussion is still exactly the same.)

When the contacts are closed, the meter reads 60mA. When the contacts are open, the meter reads zero. (Closed contacts correspond to a mark, and open contacts correspond to a space.) **Fig 1.14a** shows current (I) versus time for a steady mark and **Fig 1.14b** for a steady space. These pictures are as would be seen on a dc oscilloscope.

What happens when a telegraphic character is sent; ie when someone is "typing" something?

For initial explanation purposes assume that the keyboard can send "dots". Dots are simply constantly repeated opens and closures of the loop in perfectly even intervals. **Fig 1.14c** shows how the loop current would vary when dots are sent (and there is no loop inductance.) This is simply a square wave. During the first interval when the current is 60mA, the meter will attempt to travel from zero towards 60mA. However, if it is a typical meter, 22ms is not sufficient time for the meter to respond from zero to 60mA. Therefore, it will only get part way up towards 60mA when the loop current goes to zero. The meter will then try to return to zero. However, it was moving upwards and will require a while to stop moving upwards before it can start to move downwards. It will probably be able to start moving downwards but will not get to zero before the current goes to 60mA again, and it again has to reverse and start going upwards, etc.

Consequently, the meter will not read zero and will not read 60mA, but will hover between the two values. If the meter is sufficiently sluggish (most meters are), it will appear to stand still somewhere between 60mA and 0mA. The question is: where will it appear to remain stationary? Well, the meter is spending half its time trying to go to 60mA and half its time trying to go to 0mA. (Note that when the dots are being sent, exactly half the time the current is 60mA and exactly half the time the current is zero.) Therefore, the meter must indicate exactly half of 60 and 0, or 30mA.

If the meter is less sluggish, it will not sit steadily at 30mA but it will appear to hover or vibrate about 30mA.

Fig 1.14d shows the loop current when a single repeated character such as R is being sent. As in the previous example, the meter will spend part of its time trying to get up to 60mA and part of the time trying to get to zero. However, in this case the two portions of time are not equal. Because the meter indicates a simple average, the expected meter reading can be calculated as:
$(22 \times 0 + 22 \times 0 + 22 \times 60 + 22 \times 0 + 22 \times 60 + 22 \times 0 + 31 \times 60)/163 = 27{\cdot}6$mA. Or: $75 \times 60/163 = 27{\cdot}6$mA. Therefore the meter should read 27·6mA because this is the average.

In order for the meter to indicate the value just calculated, several conditions must be met: The steady mark current must be exactly 60mA, there is no inductance in the loop (inductance distorts the wave shape), the contacts on the keyboard are properly adjusted, the keyboard is being keyed at keyboard speed, and a machine with a 7·42-unit code is being used. These may seem to be unduly restricting, but that's life! If any one of the above conditions is not met the meter will not read exactly 27·6mA. This can be used as a good indicator for all components in the loop. However, if two (or more) of the above conditions are not met, the meter could read 27·6mA. Therefore, the above is not an infallible check, but it is a simple, useful indicator.

When the repeated character, such as R, is sent, the meter may appear to fluctuate more than with dots. The reason is that the start pulse and the first unit are both spaces; therefore, the meter has a longer time to move during this interval.

When just "typing" on the keyboard, the meter may appear to move somewhat erratically. This is to be expected because the meter is constantly trying to find an average, and each character *has* a different average (or nearly so). Also the time spent between characters is a variable depending upon the "typing" speed of the operator.

Fig 1.14a. Current in loop, steady mark condition.
Fig 1.14b. Current in loop, steady space condition.

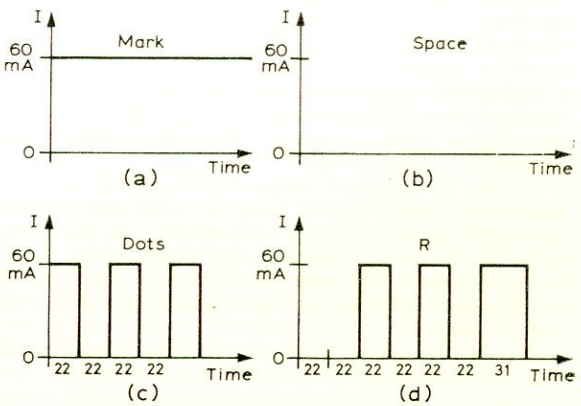


Fig 1.14c. Current in loop, dots being sent.
Fig 1.14d. Current in loop, letter R being sent.

ON-OFF KEYING VERSUS FREQUENCY-SHIFT KEYING

On-off keying of the radio carrier presents many disadvantages when applied to machine telegraphy. An operator copying cw on-off keying has at his disposal the best machine of all—his brain! He can pick out his wanted signal from often louder interference; he can read down into the noise; he can recognize a Morse character even though the sending is poor and erratic.

A machine is much more limited. It must be set to operate from a signal threshold and discard all below that threshold as noise or interference. Automatic gain control can only give very limited help, and an on-off signal that is quite strong may be wrecked by a much weaker interfering signal if the threshold is set too low. Since radio signals commonly fade up to 40dB, a voltage ratio of 100 : 1, the setting of the threshold control is, at best, a dubious compromise. One must chance losing the signal when it fades in order to block off the weak interference and noise when the signal is strong. One mutilated baud in the Murray code makes the teleprinter print the wrong character and seven and a half bauds are lost. If the baud lost happens to be a start pulse, the following character may be displaced and lost.

It may take several characters before the teleprinters again come into synchronism. Suppose, for example, letter A is transmitted. The teleprinter will send a start signal, two marks and three spaces in sequence, and then one and a half bauds stop signal. If, due to a sudden burst of interference, the start signal were not received, the receiving teleprinter would remain at rest until the first space, element 3, was received. This it would interpret as the start signal, and its mechanism would still be revolving on that character when, in fact, the next character was coming over the air. This is why the stop signal has an odd half baud in its length. If the complete character with its synchronizing signals were an exact number of bauds in duration, one dropped start signal could throw the teleprinters out of synchronism until such time as there was a pause in transmission. Even as it stands, one dropped start signal can throw the teleprinters out of synchronism for several characters, depending on their make-up, and this is the great weakness of the start-stop system.

Until the advent of frequency-shift keying it was generally recognized that start-stop Murray code signalling was not practicable over radio link circuits. Frequency-shift keying did nothing to remove the inherent weaknesses of the system, but it did provide a much more reliable radio link system so that it became possible to use start-stop signalling on point-to-point commercial circuits and keep them traffic-worthy. Commercial operators regard the use of start-stop signalling as merely a stop-gap while more sophisticated systems are coming into use.

One big advantage of frequency-shift keying is that it always has a carrier present, mark or space, and provided the wanted signal is slightly stronger than an interfering signal it will be correctly recorded. There is no touchy threshold control; the signal limiting stage preceding the discriminator fixes that, and noise cancels out in the discriminator circuit.

Two difficulties arise. First, use of automatic gain control is very limited and its time constant must be very short. This is because the mark and space frequencies, separated by less than 1 kilohertz, fade independently, and a strong mark which backs the receiver sensitivity right off on agc may be immediately followed by a weak space which would be lost if the receiver remained backed off by agc with a long time constant. In any case, unless the agc can actually follow the signals, it can give rise to some unpleasant telegraph distortion effects. The effective range of the agc is therefore tied to the dynamic range or margin of signal over which the limiter will operate effectively.

Secondly, radio signals are usually received on one or two paths simultaneously and, since the path lengths vary, the signals over different paths arrive at the receiving aerial at slightly different times. As an example, if 20ms bauds are being received by one-hop and two-hop propagation, and the second hop is arriving 3ms after the first, each first-hop baud will have 3ms of the previous second-hop baud interfering with its first 3ms. On the other hand, each second-hop baud will have 3ms of the next first-hop baud interfering with its last 3ms. If the fact that alternate bauds may be mark and space bauds is added, and the overlaps tend to cancel out in the discriminator, it will be appreciated that 6ms of the 20ms bauds are of very dubious value. Taken together with an otherwise tolerable speed difference between the teleprinter character mutilation become considerably greater. This effect occurs commonly enough when the radio signal appears to be very strong and would be expected to do nothing but print perfectly. The sophisticated cure is to use an aerial with a vertical reception angle that receives only one path. The unsophisticated cure is to reduce transmitter power until the weaker path fades below trouble level.

It is multiple path effects that set a term to the maximum keying speed that can be achieved in radio telegraphy. It must be borne in mind that the effect of distortion on the telegraph receiving equipment depends on the ratio of the time taken to complete the sensing process of the baud polarity and the actual length of the baud. In this respect there is scope for amateur ingenuity.

ANALYSIS OF A SQUARE-WAVE

It may be shown that any recurrent wave consists of a fundamental sinusoidal wave of the same frequency, together with a number of the harmonics of that frequency. **Fig 1.15a** shows how a sine wave with its third harmonic in the correct proportions approximates to the shape of the square waves transmitted in telegraph circuits. In **Fig 1.15b** the fifth and seventh harmonics are added, making the agreement still closer, and if all the odd harmonics to infinity could be added the result would be an exactly square wave.

In the teleprinter Murray Code operating at 50 bauds, each signal lasts 20ms so that the number per second is about 50, and the maximum possible number of alternations from mark to space and vice versa is 25/s. When such signals are analysed the fundamental frequency is 25Hz, and the other harmonics giving the square shape to the wave are 75, 125, 175, 225Hz, etc.

When two or more mark or space signals are sent in succession, the resulting wave can likewise be shown to consist of a sine wave plus harmonics, but of frequency lower than when the mark and space signals are consecutive.

If the square topped signals **(Fig 1.16a)** from a teleprinter are passed through a filter which will not pass very high frequencies, the shape of the signals in the output of the filter will be distorted, as shown in **Fig 1.16b**. Further, if the filter will not pass any of the harmonics but only the

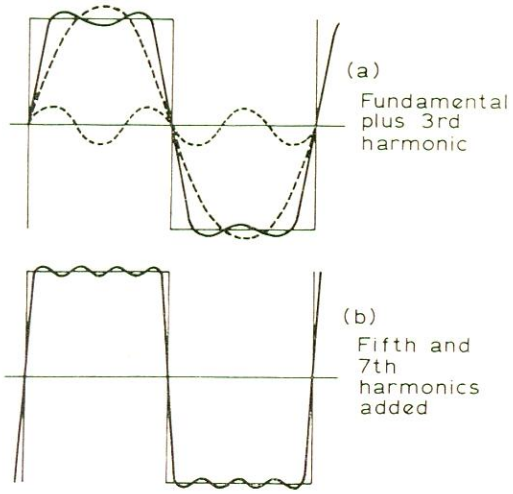


Fig 1.15. See text.

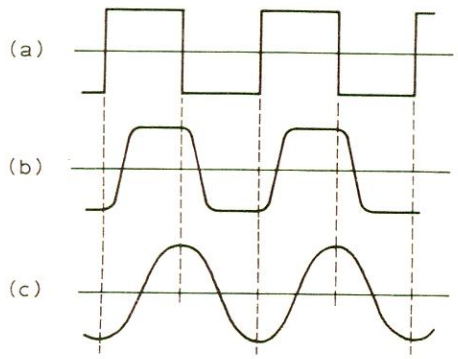


Fig 1.16. See text.

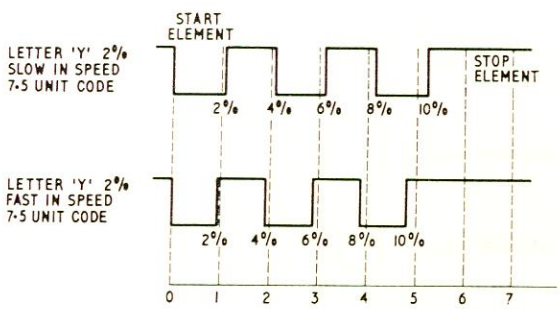

START ELEMENT
LETTER 'Y' 2% SLOW IN SPEED 7·5 UNIT CODE
STOP ELEMENT
2% 4% 6% 8% 10%
LETTER 'Y' 2% FAST IN SPEED 7·5 UNIT CODE
2% 4% 6% 8% 10%
0 1 2 3 4 5 6 7

Fig 1.17. Distortion caused by a speed error of the transmitter driving motor.

fundamental keying frequency (25Hz), then the output will be sinusoidal as in **Fig 1.16c**.

Since the high harmonics tend to cause interference with neighbouring circuits due to induction, as well as necessitating a wider frequency band, they are often removed at the transmitter by means of a filter.

TELEGRAPH DISTORTION

In start-stop telegraph systems, distortion is defined as being the ratio to the unit element of the maximum difference, irrespective of sign, between the actual and theoretical intervals separating any characteristic instant of modulation from the beginning of the start element immediately preceding it. It must be noted that this definition relating to a telegraph system comprising a transmitting device and receiving relay may bear no direct relation to the actual shape of the signal voltages or currents in the line or radio link used. In practice the link will have its own signal shaping networks as its characteristics demand.

Distortion in a start-stop telegraph transmitter that is in good order can usually be relied upon to give signals accurate to within 1ms, corresponding to a distortion of $1/20 \times 100 = 5$ per cent at a speed of 50 bauds. If, however, there were a motor speed error, this would produce a fixed amount of distortion for each element which is cumulative during the character, so that the last character element will become the most distorted. For example, assume that the motor speed is 2 per cent fast. This will give a transmission speed of 51 bauds in a nominal 50 baud system and produce 2 per cent distortion per element throughout the character, thus giving a distortion of 10 per cent on the start of the fifth element. This is illustrated in **Fig 1.17**. To this figure of 10 per cent must be added the inherent distortion of the transmitter, as previously described, giving a total distortion of 15 per cent. The overall quoted percentage of distortion would remain the same if the transmitter motor speed were 2 per cent slow in the example shown.

The previous example has shown two types of distortion that fall into separate categories, these being known as "fortuitous distortion" and "characteristic distortion". Another common form of telegraph distortion is known as "bias distortion".

Bias distortion may also occur in a telegraph transmitter and is usually a mechanical problem produced by maladjustment or worn parts associated with character element change over mechanism.

The types of distortion can therefore be summarized as follows:

Fortuitous distortion

This is a purely random displacement of the signal transitions. It generally emanates from line pick-up, noise, selective fading, dirty contacts or similar causes. In some situations, a bad offender is alternating current from power supply lines, which may cause a "wandering bias" due to a beat effect with the signalling speed. This is illustrated in **Fig 1.18**.

Characteristic distortion

This is essentially repetitive in nature and takes the form

of consistent distortion of one or more character elements of a signal.

If, for example, the start element were long for each character, due possibly to a slow pick-up speed of the transmitting selector cam, this would constitute characteristic distortion, as would the speed error of the motor as mentioned previously. Another example would be what is known as a split element; where, for example, the fourth element of the character reverts to mark for a short time while the element should be a space. A long start element and split element is illustrated in **Fig 1.19**.

Bias distortion

This may be defined as the uniform lengthening, or shortening, of space elements at the expense of mark elements. The result is that the total duration of one mark and one space element is constant. Where the space element is lengthened, the system is said to possess space bias; where the mark element is lengthened, the system possesses mark bias. This is shown in **Fig 1.20**. This type of distortion can arise from many causes, ie a maladjusted relay in the system or an inaccurately tuned radio receiver in a frequency shift demodulation receiver.

On some single-current systems, the mark elements may be lengthened due to excess capacitance.

If during the space to mark transitions the line capacitance is quickly charged from a low impedance source at the telegraph transmitter after the mark to space transition, the system is open-circuited and the charge on the excess capacitance has to leak away through the receiving terminal, giving a slow lagging edge. This is known as end distortion, and a correctly biased relay or receiver would operate about the centre of the waveform as shown in **Fig 1.21**, introducing about 20 per cent distortion in the example.

Bias distortion must be kept to a minimum.

Having defined some of the sources of telegraph distortion in the transmitting direction, if a receiving printer is now connected to the line, provided the distortion is no greater than 50 per cent, the ideal receiving printer will produce perfect copy. The assumption of an ideal receiver is one in which the instant of code selection is at a point one half an element length in time after the actual signal transition would have occurred in a transmission with zero distortion. This condition will never exist with a mechanical decoding type of receiving printer.

In practice, a receiving teleprinter in good order will require the correct signal element for a duration of 10 to 20 per cent of the total element duration about the centre of the code element. This variation exists due to the various methods of conversion from the electrical input to the printed character; an average accepted figure is 20 per cent. If the line signals to the teleprinter receiver are distorted 40 per cent, reception will not be impaired. This acceptance of 40 per cent distorted signals means that the teleprinter has what is known as a 40 per cent margin. This is illustrated in **Fig 1.22**. Measurement of receiver margin may be made by means of artificially distorted signals, in which the code elements are displaced by known amounts with respect to the beginning of the start element. This effect is most commonly produced by lengthening or shortening of the start element.

Some teleprinters are equipped with an orientation device, also known as a range finder, whereby the operation of the selecting mechanism can be advanced or retarded with

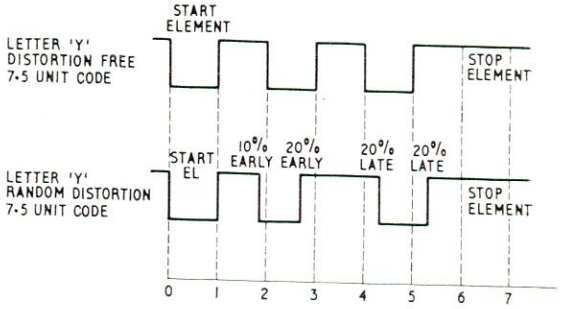


Fig 1.18. Fortuitous distortion.

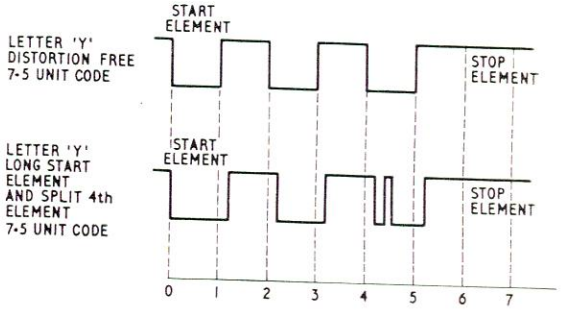

START ELEMENT
LETTER 'Y' DISTORTION FREE 7·5 UNIT CODE
STOP ELEMENT
START ELEMENT
LETTER 'Y' LONG START ELEMENT AND SPLIT 4th ELEMENT 7·5 UNIT CODE
STOP ELEMENT
0 1 2 3 4 5 6 7

Fig 1.19. Characteristic distortion.

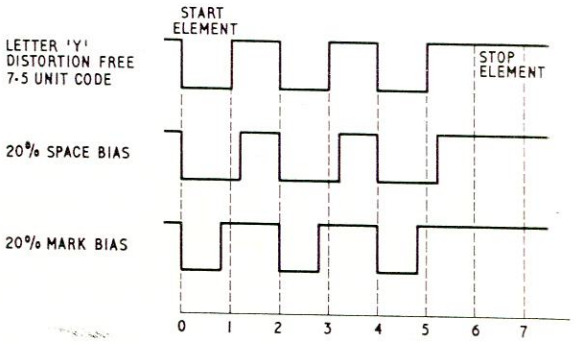


Fig 1.20. Bias distortion.

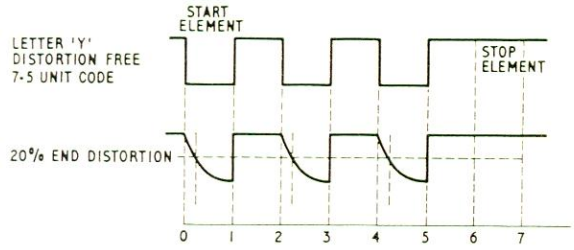


Fig 1.21. End distortion.

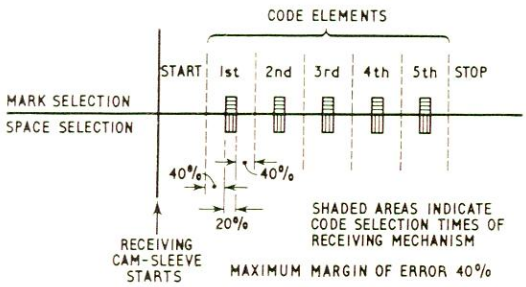


Fig 1.22. Teleprinter receiver margin.

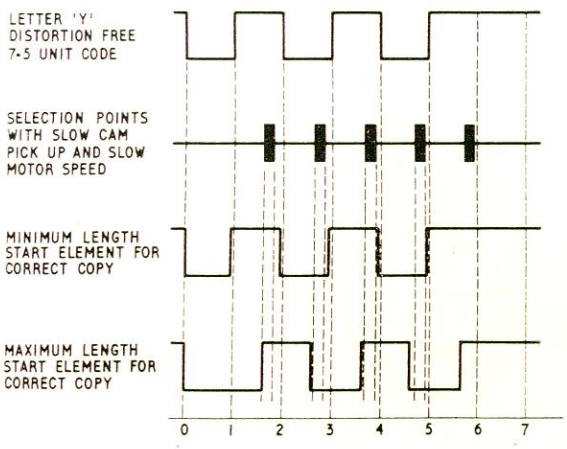

LETTER 'Y' DISTORTION FREE 7-5 UNIT CODE
SELECTION POINTS WITH SLOW CAM PICK UP AND SLOW MOTOR SPEED
MINIMUM LENGTH START ELEMENT FOR CORRECT COPY
MAXIMUM LENGTH START ELEMENT FOR CORRECT COPY
0 1 2 3 4 5 6 7

Fig 1.23. Motor speed error and receiver margin.

respect to the commencement of the start signal. With careful use of the range finder the margin of the receiver can be determined and any "small" mechanical bias may be corrected by setting the range finder to the mid point of the range as determined from the maximum and minimum position at which perfect copy can be printed from an undistorted transmission.

Teleprinter motor speed is of prime importance in the receiving mode, as any error will advance or retard the character sampling point of the receiver, and hence reduce the margin of distortion acceptable for error-free printing.

Similarly, any mechanical bias, or selecting cams that are slow to accelerate to their correct speed from rest, will reduce the margin. In the case of the motor speed and the slow pick-up of the selecting cams, this will produce a one-sided range and reduce the margin. An example of this is shown in **Fig 1.23** where the margin is 5 per cent in one direction and 50 per cent in the other.

The "range" of a receiving teleprinter is the sum of the margin measured in each direction, for the lengthening and shortening of the start element, or alternatively marking or spacing bias. For example, if the printer margin is such that correct printing were obtained with up to 15 per cent shortening of the start element, and 35 per cent lengthening of the start element, the margin would be quoted as being 15 per cent and the range 50 per cent. By use of the range finder or orientation device, as fitted to some printers, the margin may be improved by offsetting the range finder from its mid-point by 10 per cent in a direction to shorten the start element artificially. The margin would then become 25 per cent for long or short start elements, the range still remaining at 50 per cent.

THE POLAR RELAY

The movement of the armature in a polarized relay depends on the magnitude and sense of the current in its operating coil. The polarizing characteristics are determined by the use of one or more permanent magnets, and movement of the armature is achieved by the redistribution of the permanent magnetic flux, by current flowing in the appropriate direction in the operating coil. Provided there is a mechanical and magnetic balance within the relay, with no current flowing in the operating coil, true polar operation may be achieved with the maximum sensitivity and stability.

The layout of the magnetic circuit within a polar relay will, in most cases, be similar to one of the basic circuits shown in **Fig 1.24**. In each illustration, the flux generated by the permanent magnets is shown by dotted lines, and the flux due to current within the operating coils by full lines. The pivots may be in the form of cones, rollers, knife edges, or the more common, and less troublesome, hinge spring.

Fig 1.24a shows the simplest form of magnetic circuit in which the armature carries the whole of the permanent flux, being divided into two paths through the pole pieces and the yokes on which the operating coils are mounted.

The polar relays shown in **Fig 1.24b** and **c** are of more recent design, where the armature does not carry the whole of the permanent flux, but only an out of balance flux. In this configuration the longitudinal flux passing through the armature will be zero when in the neutral position, or mid way between the pole pieces. The operating coils for relays of this

configuration are concentric with the armature, having sufficient clearance for armature movement.

Relays of the form shown in **Fig 1.24c** have their operating coils in two halves, one mounted each side of the pivot.

Fig 1.24d illustrates the most common form of polar relay that may be found in current equipment, with the exception of the mercury wetted contact relay. The magnetic circuit of the relay employs two permanent magnets, the fluxes of which unite in the armature and flow through it longitudinally. The reversals circuit is reduced to the simplest possible form, having only a single air gap in which the armature moves. Thus, the longitudinal reluctance of the armature is in circuit only with the permanent magnets, and the signal winding has only to overcome the lower transverse reluctance of the armature. The core, carrying the reversals winding, connects points on the structure which are at the same magnetic potential; therefore, when the armature is central the core is not traversed by the polarizing flux of the permanent magnets. Hence the cross-section of this core need only be made large enough to carry the reversals flux. Thus the diameter of the signal winding can be kept small and the resistance of the winding correspondingly reduced. Those portions of the magnetic current which are traversed by both the polarizing and the signal flux are made of ample cross-section so that their reluctance is negligible. The reluctance of the upper air gap between the inner poles of the permanent magnets is relatively high, hence this air gap may be made wide compared with the lower or working gap, which should be kept small.

Damping of the contacts in a polar relay is essential, or the armature will continue to vibrate for an appreciable period of time after the closure of the contacts and cause irregularity in the repetition accuracy of short duration pulses.

Contact chatter is reduced or eliminated by the use of anti-chatter springs mounted to the armature and supporting the moving contacts, **Fig 1.25**. The two free ends of the contact springs bear together by a predetermined amount as specified by the manufacturer. Alternatively, contact chatter is controlled by the use of damped compliant mountings for the side contacts, **Fig 1.26**. To introduce the correct degree of damping, each side contact is mounted on a bowed spring, arranged to slide on a friction screw, the position of which is determined during manufacture. The pressure between the spring and friction screw is adjusted such that the armature is allowed to come to rest as quickly as possible after the closure of the contacts.

The operation of the mercury wetted contact relay deserves special consideration. This type of relay requires the minimum of operating power and has the advantage of contact arrangements that do not bounce. Contact resistance is kept to a minimum together with high reliability.

The mercury wetted contact relay has a small disadvantage in that it must be mounted upright, as indicated on the manufacturer's outer protective cover. The magnetic circuit of this relay is as shown in **Fig 1.27**. This type of relay is not as robust as its more conventional counterpart owing to its method of construction, and being a sealed unit there is no possibility of maintenance. However, the life expectancy of this type of relay is normally in excess of 10^9 operations at maximum contact rating with adequate contact protection. Details of the construction and operation of the mercury wetted contact relay will be found in Chapter 6.

LOW LEVEL SIGNALLING

With the increase in the use of data-processing equipment in the communications field, there is an ever-increasing demand for a signalling standard suitable for use with modern semiconductor technology.

The International Telegraph and Telephone Consultative Committee of the International Telecommunication Union, have a recommended standard for the interconnection of

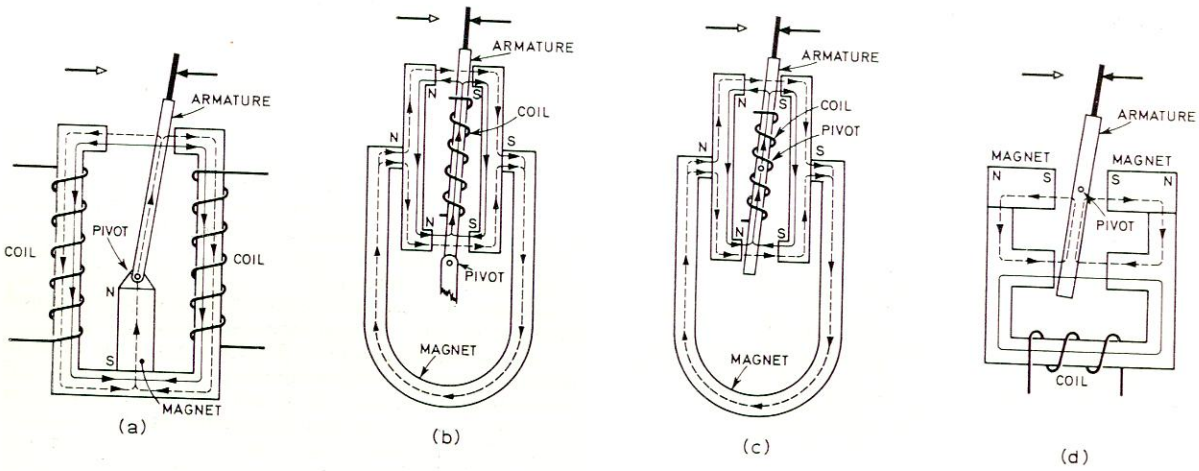


Fig 1.24. See text.

data-processing terminal equipment and data communication equipment. The following is an extract from their Recommendation V.24 as applicable to the amateur station:

Line of Demarcation

The interface is the definition of the circuits at the interchange point of a connection which occurs at a plug connector, between the data communication equipment and the data-processing terminal unit equipment.

The following interchange circuits shall be uniquely allocated to pins on this connector.

Circuit 1—Protective Ground or Earth

This conductor shall be electrically bonded to the machine or equipment frame. It may be further connected to external grounds as required by applicable regulations.

Circuit 2—Signal Ground or Common Return

This conductor establishes the common reference potential for all interchange circuits except the protective ground or earth (Circuit 1). Within the data communication equipment this circuit shall be brought to one point, and it shall be possible to connect this point to protective ground or earth by means of a wire strap inside the equipment.

Circuit 3—Transmitted data

Direction: **TO** data communication equipment.

The teleprinter transmitting contacts are connected to this circuit and also the input of any transmitting signal converters, ie afsk or fsk oscillators.

Circuit 4—Received data

Direction: **FROM** data communication equipment.

The teleprinter receiving electromagnet signal converter is connected to this circuit and also the output from any terminal or signal processing unit.

Circuit 5—Request to send

Direction: **TO** data communication equipment.

The **ON** condition is maintained whenever the data-processing terminal unit has information ready for transmission or being transmitted. In amateur use this circuit may be used to turn the transmitter on for transmission and also *enable* the afsk or fsk oscillator as appropriate.

Circuit 6—Ready for sending

Direction: **FROM** data communication equipment.

The **ON** condition is a response to the **ON** condition on Circuit 5, delayed as may be appropriate to the equipment. For use by the amateur, this **ON** condition could be activated by the presence of rf from the transmitter and then *enabling* the teleprinter transmitter.

Circuit 7—Data set ready

Direction: **FROM** data communication equipment.

The signals on this circuit are generated by the local data set to indicate that it is ready to operate (receive or transmit.) The **OFF** condition shall be used to indicate:

(*a*) any abnormal or test condition which disables or impairs any normal function associated with the class of service being furnished.

(*b*) that the communication channel is switched to an

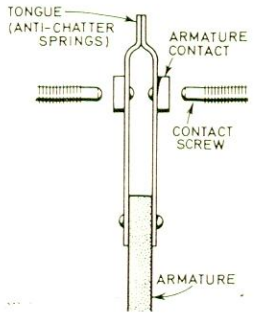


Fig 1.25. Relay tongue anti-clatter springs.

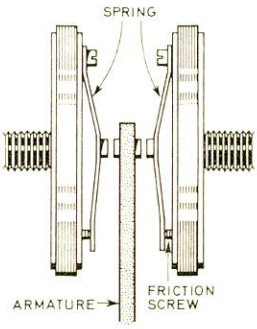


Fig 1.26. Damped compliant mounting for side contacts.

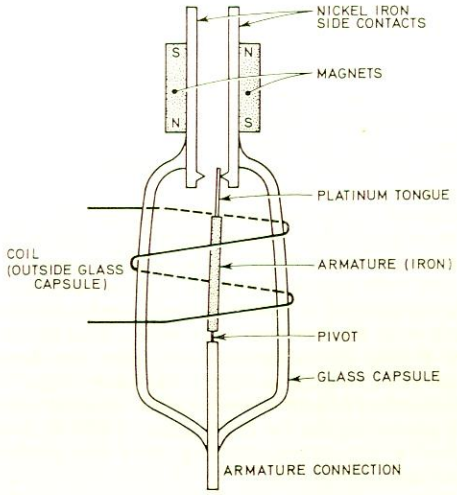


Fig 1.27. Magnetic layout for polarized mercury wetted contact relay.

alternate means of communication (eg alternate voice telephone).

(*c*) that the local data set is not connected to a communications channel.

The **ON** condition shall appear at all other times.

Circuit 8—Connect data set to line

Direction: **TO** data communication equipment.

Signals on this circuit are used to control switching of the signal converter to be connected to the communication channel. The **ON** condition causes the signal converter to be connected to the communication channel, and also to maintain the connection in the case of an automatic transmitter. The **OFF** condition removes the data equipment from the channel, thus enabling the same equipment to be used for other purposes. The **OFF** condition shall not disable the operation of any calling circuit.

Circuit 9—Data carrier detector

Direction: **FROM** data communication equipment.

Signals on this circuit are used to provide an indication that the data carrier is being received. For the amateur, this would indicate that the tones of an afsk transmission were being received, or that there was a carrier on the fsk frequency in use. When the data carrier is lost because the transmitting signal converter is turned **OFF** or there is a fault condition, the **OFF** condition follows after an appropriate time delay. Under conditions whereby the signal converter is arranged for local copy, this circuit may respond to either the local or remote transmitting signal converter.

These nine circuits are the most important. Others are allocated for such functions as timing reference and frequency changing of the communication equipment. A fuller description of the various circuits and their functions may be found in the report of the IIIrd Plenary Assembly, *Blue Book*, Volume VIII, Data Transmission.

Electrical signal characteristics

The maximum open-circuit voltage to ground (either frame ground or signal ground) on any interchange circuit shall not exceed 25V, and the maximum short-circuit current flow between any two conductors (including grounds) shall not exceed one-half ampere.

Any circuitry used to generate a signal voltage on an interchange circuit shall be so designed that no damage will be caused by either an open- or short-circuit condition to either protective or signal ground.

For Circuit 3 (transmitted data) and Circuit 4 (received data) the signal shall be considered in the "marking" condition when the voltage on the circuit is more negative than −3V with respect to signal ground, and the signal shall be considered in the "spacing" condition when the voltage is more positive than +3V with respect to the signal ground. During the transmission of data, the "marking" condition shall be used to denote the binary state "**ONE**" (eg hole punched in paper tape) and the "spacing" condition shall be used to denote the binary state "**ZERO**". Note that "marking" is the normal condition on a data circuit when no signals are present.

In certain countries, including the UK and North America, the connections to dc telegraph circuits may be of reversed polarity.

For all control circuits, the control functions shall be considered **ON** when the voltage on the circuit is more positive than +3V, and **OFF** when more negative than −3V, with respect to signal ground.

In some applications it may be necessary for fail-safe operation to detect either the power-off condition in the equipment, or a fault condition in the interconnection wiring. Circuits 5, 7 and 8 are required to indicate the **OFF** condition in fail-safe operation.

The operation of the circuitry that receives data and control signals from an interchange circuit shall be dependent only on the signal voltage, as specified above, and should, therefore, be insensitive to the rise time, fall time, presence of signal overshoot, etc. The design of this circuitry shall minimize any circuit time constants which would delay the circuit response.

For both data circuits and timing signal circuits, neither the rise time nor fall time, through the range (+3 to −3V) in which the signal condition is not defined, shall exceed 3 per cent of the nominal duration of a signal element. This is illustrated in **Fig 1.28**.

Equivalent Circuit

Fig 1.29 is the equivalent circuit schematic. The following conditions shall apply:

1. Vo shall not be greater than ± 25V.
2. When the interchange circuit is short-circuited, the circuit shall not be damaged and the short-circuit current shall not be greater than $\frac{1}{2}$A.

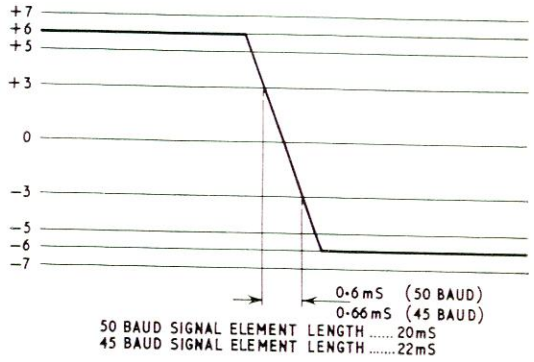


Fig 1.28. Maximum rise and fall times of low level signals at instant of modulation.

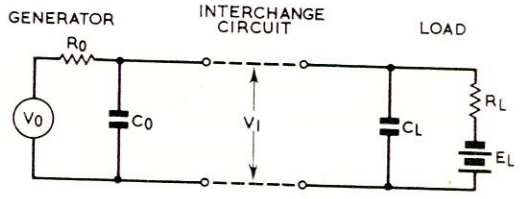


Fig 1.29. Low level telegraph signalling equivalent circuit.

3. R_O is not otherwise specified, except that, when R_L is 3,000Ω and E_L is zero V_I shall not be less than ± 5V. Good design practice indicates that R_O should be made small.

NOTE. *The nominal service voltage at this point is 3V; the 5V specification applies only to this condition* (3).

4. E_L shall not be greater than ±2V.

5. R_L shall not be less than 3,000 or more than 7,000Ω.

6. C_L shall not be greater than 2,500pF.

7. C_O is not specified, but must be considered in relation to the rise and fall time requirements.

8. The circuitry that receives signals from an interchange circuit shall recognize the binary signal when V_I equals ± 3V. The signal condition is not defined when V_I is in the range between +3 and −3V.

In order to avoid inducing voltage surges on interchange circuits, signals from interchange circuits should not be used to drive inductive devices, such as relay coils.

The signal ground (or common return) potential may be offset (biased) from protective ground (earth) by up to ± 5V if required, and if the wire strap is not present.

Amateur use of low level signalling

For compatibility between amateur equipment and commercial telegraph equipment designed for low level signalling, it is suggested that the following standards be adopted.

Transmitter output voltage, positive (mark) and negative (space) 6 ± 1V and balanced to within ± 10 per cent.

Transmitter source impedance, not exceeding 100Ω for currents of magnitude less than 0·01A. The maximum short-circuit current not to exceed 0·1A.

Transmitter waveform to comply with the recommendations of the CCITT.

Receiver input resistance shall be 6,000 ± 1,000Ω.

Receiver sensitivity should be such that the correct operation of the device shall be effected on voltage excursions of ± 3V. The maximum sensitivity should not be much better than ± 0·5V to ensure adequate stability of open-circuited receiver input. Whatever nominal operating voltage is chosen within these limits the positive and negative operating points should be within 10 per cent of each other to minimize time distortion.

The major difference in the North American standards for low level signalling is in the specification for receiver input resistance. This is specified such that the maximum current supplied by the transmitter is limited to a maximum of 1mA. Thus the combined input resistance of all receivers connected to one interchange point shall be 6,000Ω minimum.

RADIO RECEIVER SENSITIVITY

There are several means of specifying the sensitivity of a receiver. Probably the two most common methods are the microvolt sensitivity and the noise figure. These two methods are directly related. In order to discuss them, it is necessary to discuss some of the characteristics of noise.

White, Gaussian Noise

Noise can be defined as any unwanted signal. This definition is too broad for practical work so a narrower definition is required. The most common form of noise found in radio communication work, especially at vhf and above, is white, Gaussian noise. White refers to frequency components that range over a very wide band (analogous to white light that contains all frequencies of the visible spectrum in equal amounts). Gaussian refers to the amplitude characteristics; a Gaussian distribution is one that is completely random (unpredictable) and follows a normal-law-of-error characteristic. The noise heard from a receiver when no station is being received is Gaussian noise; it may or may not be white depending upon the detector in the receiver and the frequency response characteristic of the audio stages.

White, Gaussian noise can be generated in many ways. Valves and transistors generate it. Also, any resistor at a temperature above absolute zero generates such noise. The noise voltage generated in a resistor is:

$$E = \sqrt{4k\,TBR}$$

Where k is Boltzmann's constant = $1{\cdot}38 \times 10^{-22}$ joules per °K,

T = temperature of resistor in °K,

B = frequency band across which voltage is measured in Hz, and

R = resistance in ohms.

Because noise comes from any amplifying device as well as from any resistor (including the lossy part of transmission lines), any signal will contain some noise. The lower limit of receiver sensitivity is determined by noise contamination.

Signal to Noise Ratios

A sometimes useful indicator of the condition of a signal or its degree of noise contamination is the signal to noise ratio (SNR). The ratio is calculated by dividing the signal power in watts by the noise power in watts. The signal to noise ratio in dB is 10 $\log_{10}$ of the SNR.

MICROVOLT SENSITIVITY

The voltage sensitivity of a receiver is determined by applying a signal to the aerial terminals and adjusting the signal level until a certain signal to noise ratio appears at the receiver output. Noise will be introduced into the receiver output through two (at least) mechanisms. The signal generator produces noise; this results from the internal resistance of the signal generator producing the thermal noise discussed earlier. The amplifying devices within the receiver produce noise; usually the major contributor is the first rf amplifier and/or mixer. (In some cases the input network within the receiver between the aerial terminals and the first rf amplifier gives more noise than the amplifying devices!)

If a perfect receiver (one contributing no internal noise) were being tested, a 0dB SNR at the output (SNR = 1) would be obtained when the signal generator voltage equalled its own internal thermal noise. For example, if the generator impedance were 50Ω and its temperature 290K (= 17°C = 63°F), and the perfect receiver had a 6kHz noise bandwidth, the thermal noise would be 0·03μV and the signal generator would have to provide a 0·03μV signal to give the 0dB SNR.

Because a 0dB SNR is too low for convenience, an SNR of 9·5dB is commonly used. This would require a 0·09μV signal from the signal generator for the assumed 50Ω, 290K, 6kHz noise bandwidth.

If, on the other hand, the receiver noise bandwidth were only 600Hz, then a 9·5dB SNR would require a 0·028μV signal from the generator. With a 60kHz receiver bandwidth the signal generator would have to supply a 0·28μV signal for a 9·5dB SNR.

It should be noted that the amount of signal voltage required for a given SNR at the output of a receiver goes as the square root of the bandwidth; hence, the wider the bandwidth the greater the signal required to give a certain SNR. This means that a television receiver with a bandwidth of 6MHz requires a hundred times more signal voltage at the aerial for a given SNR at the output than does a telegraph receiver with a 600Hz bandwidth.

Perhaps it is worthwhile to explain why a 9·5dB SNR was used in the above example; 9·5dB equals a ratio of 9. Generally, for ease of measurement the signal-plus-noise to noise ratio is measured rather than the signal to noise ratio. In order to measure signal to noise ratio, the meter on the output of the receiver has to reject noise while it is measuring the signal. This can be accomplished rather easily if a pure tone is being used to modulate the signal generator, because a notch filter is simple to construct—however, many people do not possess them. If a complex signal is used to modulate the signal generator it is difficult, at best, to separate the signal and noise. Therefore, it is usually only possible (or convenient) to measure signal-plus-noise output. A signal to noise ratio of 9 (9·5dB) is a signal-plus-noise to noise ratio of 10 (10dB).

If other than a perfect receiver were being tested, the microvolt sensitivities given above would be larger numbers (worse) because the noise present would be greater. The receiver would be introducing noise that would add to the noise coming from the signal generator making the "background" noise higher and requiring a greater signal level from the signal generator.

NOISE FACTOR

The microvolt sensitivity of a receiver is dependent upon the bandwidth; therefore, it is not adequate for rating a receiver unless the bandwidth is also specified. (If receivers with identical bandwidths are being compared it is quite useful.) Noise factor is defined as the signal to noise ratio at the input of a receiver divided by the signal to noise ratio at the output of the receiver. This is a very useful rating because the bandwidth of the receiver does not need to be specified.

There are at least three ways to measure the noise factor of a receiver.

1. Use the definition given and measure the signal to noise ratios at the input and output.

2. Use a technique requiring a signal generator to measure the receiver gain, the noise bandwidth, and the microvolt sensitivity.

3. Use a noise generator and the formula:

$NF = 10 \log_{10} (EN/Y\text{-}1)$.

Comments on the above:

(1) The input signal to noise ratio is hard to measure, thus this technique, although a convenient mathematical definition, is hard to implement.

(2) The noise bandwidth must be known. This requires a fairly tedious set of measurements. Measuring the receiver gain is generally inaccurate because most signal generators are not properly calibrated and/or not used properly. Therefore, scratch this method.

(3) When using a noise generator, the bandwidth and gain are not important because one is measuring noise with noise. Also, most noise generators put out a small amount of noise that is the same order of magnitude as that generated within the receiver. Therefore, no large amounts of attenuation are required as they are when signal generators are used and greater accuracy is possible with noise generators.

Receiver Characteristics

A very meaningful description of a receiver's performance can be obtained by looking at a graph of the signal to noise ratio at the audio output versus the signal to noise ratio at the aerial terminals. Such a graph is shown in **Fig 1.30**.

Taking a single sideband (ssb) voice receiver first (the curve labelled ssb), it can be seen that regardless of the signal to noise ratio at the aerial terminals, the signal to noise ratio at the speaker terminals is the same as at the aerial terminals. For example, if the signal to noise ratio at the aerial terminals is 0dB, it is zero dB at the loudspeaker; a 20dB signal to noise ratio at the aerial will result in a 20dB signal to noise ratio at the speaker. These values assume that the receiver has a noise factor of 1 (noise figure of 0dB, a perfect receiver) and that the bandwidth of the receiver is exactly that required for the signal being received. The latter is usually true, or nearly so, but the former definitely is not, especially in the vhf range. If the noise factor were 3 (noise figure, 4·8dB, a pretty good receiver), the curve would be shifted to the right (or the horizontal scale shifted to the left) by 4·8dB. That is, a 4·8dB SNR (signal to noise ratio) at the aerial would result in a 0dB SNR at the speaker, and a 24·8dB SNR at the aerial would result in a 20dB SNR at the speaker.

An interesting sidelight is that the noise figure has a pronounced effect upon the SNR for weak signals, but not much for strong signals. A degradation from 4·8dB SNR at the speaker to 0dB is very noticeable, but a decrease from 24·8 to 20·0dB SNR is hardly noticeable.

In the case of an a.m. receiver the situation is somewhat different. The a.m. and ssb curves are the same except for SNRs near the origin where the dashed line applies for a.m.

Assuming that the receiver bandwidth is matched to the signal (a 6kHz bandwidth for a baseband signal of 3kHz),

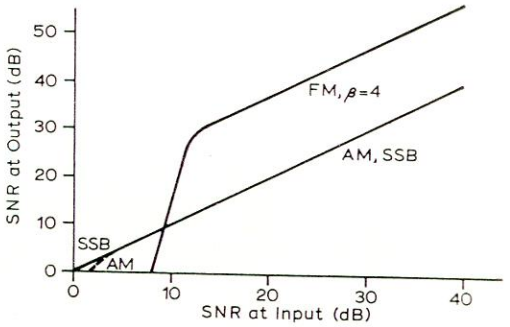


Fig 1.30. Receiver performance-graph, signal to noise ratio at the af output against signal to noise ratio at the aerial.

the performance is the same as with an ssb signal (and an ssb receiver) at the higher signal levels. However, when the signal gets quite noisy the SNR at the output falls below that at the aerial terminals! The explanation as to why this happens requires describing an a.m. detector in detail.

Most of the readers have noticed that when listening to an a.m. signal on short-wave, a dip in signal strength due to fading will result in only noise and if the signal fades far enough, no sound at all. The effect is somewhat like ocean waves rolling on the signal.

The net result is that ssb is better for very weak signal work than a.m. If the receiver were other than perfect, the curve would be moved to the right as for the ssb case.

With fm the situation is more complex. Again, it will be assumed that the receiver is one designed for the bandwidth of the signal being received. This means that if the total signal bandwidth is 36kHz, the receiver bandpass is 36kHz, etc. For the sake of discussion, assume that a 3kHz tone is being used to frequency modulate the transmitter. Further assume that the modulation index is 4. A modulation index of 4 with a 3kHz modulating signal gives a nominal deviation of plus and minus 12kHz. The actual bandwidth is then 24kHz plus four times the modulating frequency (a "rule of thumb"), or 24kHz + 12kHz, giving a total bandwidth of 36kHz.

For relatively high SNR at the aerial terminals, the portion of the fm curve that is parallel to the ssb-a.m. curves applies. It can be seen that the signal to noise ratio at the speaker terminals is higher than at the aerial terminals! For example, with a perfect fm receiver receiving a 3kHz signal with a modulation index of 4 and a 20dB SNR at the aerial terminals, the SNR at the speaker terminals is 37dB! This means than when using fm, the signal to noise ratio is improved by the receiver, or that fm is better than a.m. or ssb. If the modulation index were 8 (3kHz baseband requires a bandwidth of about 60kHz compared with 6kHz for a.m. and 3kHz for ssb) the results would be even better.

The fm results are actually as good as portrayed and lead to such claims as "fm is noise free", etc. The improvement in results over a.m. or ssb is commonly referred to as exchanging bandwidth for noise.

Unfortunately, there is a price to pay (other than the large bandwidth required). As the signal at the aerial decreases, the curve suddenly heads downward. The knee in the curve is referred to as the threshold of full improvement or the second threshold of improvement. Once below the knee, the signal degenerates very rapidly. The point where the fm curve crosses the a.m. or ssb curve is called the threshold of improvement or the first threshold of improvement.

The reason for the fm curve shape is the capture effect. When two signals on or near the same frequency are present, the stronger signal tends to dominate the output or to capture the receiver from the weaker signal. With an a.m. receiver, when two signals are present on or near the same frequency, a heterodyne results and copy is difficult unless the difference in signal strengths is great. With fm only a slight difference in signal strengths allows the stronger signal to suppress the weaker. Heterodynes are relatively uncommon in fm because the two signals have to be very close to the same strength to produce one.

Whether one of the signals is actually a signal or just noise is relatively unimportant. When both noise and a signal are present the stronger captures. This accounts for the steep rise in output SNR for a small increase in input SNR in the threshold regions. Once the signal has completely captured the noise, the noise is suppressed by a constant amount as shown for the portion of the curve above the threshold of full improvement.

A curious fact is related to the location of the threshold of improvement. Notice that the signal to noise ratio is fairly high before the signal begins to capture. The capture would take place with a 0dB ratio if both were signals. The reason the signal has to be so much higher than the noise is related to the statistical properties of noise. Noise has large peaks, therefore, its rms value is much below its peak value (which is somewhat nebulous). Therefore, the noise will momentarily capture the receiver even when its rms value is several dB below the rms value of the wanted signal.

Attempts at moving the thresholds toward the origin in order to make fm better with weak signals are referred to as "threshold extension" techniques.

The steep portion of the fm characteristic in the threshold region means that when an fm signal gets into this region it is capable of rapidly being "swallowed up" by noise with only a very small change in signal strength. That is, when fm is good, it is really good, but when it is bad, it's gone.

The fm curves can be used to explain why a low noise preamp can sometimes make such a vast improvement in an fm receiver. If an fm receiver is operating in the vicinity of the threshold of improvement (first threshold), a slight movement of the curves to the left (lowering the noise figure and consequent raising of the SNR at the aerial terminals) will result in a much greater change in the SNR at the output.

All the considerations apply when rtty is being used. It is noteworthy that essentially all rtty is fm (fsk or afsk or fm).

CHAPTER 2

TELEPRINTERS

THE central item in any radio teleprinter station is the teleprinter. There are many types available but they follow the same basic principle, that is, they have a mechanism for receiving incoming dc signals and converting these into a printed copy, either in the form of a message on a long paper tape or on a roll of paper. They are driven by a motor, the speed of which must be held steady within close limits. Most have a keyboard to enable the generation of a message in the form of dc pulses, although some are manufactured as receiving only (RO) machines and have no keyboard. All types must operate for considerable periods of time with the minimum of maintenance.

In this chapter various teleprinters are covered in some detail and the mechanical means by which the basic requirements are obtained are described. It should be understood that teleprinters are complex machines and although built to high engineering standards they require careful adjustment and lubrication to obtain the best results. Therefore, before attempting any adjustment the operating principles of the machine should be fully understood. A well maintained teleprinter in the amateur's shack with low duty cycle compared with a commercial circuit will give years of trouble-free service.

The purpose of fitting motors to teleprinters, reperforators etc is to provide power to operate the transmission and receiving machinery. To provide a satisfactory function the motor must run at a constant speed; so that the local and distant machines do not go out of synchronism, it should have a high starting torque and should run with minimum maintenance.

The three types of motor commonly used on teleprinters are ac mains synchronous; dc shunt field, governed; and ac or dc series field, governed.

Shunt Field Motor

Fig 2.1 shows the connections of a shunt field motor. In this arrangement the field is connected directly to the supply and so the current in the winding is constant. Because of this the speed is nearly constant under all conditions of load, but the starting torque is rather low.

To obtain the best performance from a shunt field motor the arrangement of **Fig 2.2** is normally used. In this method of operation, a high field current gives a low speed and a lower field current gives a higher speed. At rest, the starting contacts are closed, shorting the governor resistor. When power is applied, because there is no armature motion and consequently no back emf generated, the flux developed between the armature and the field is high, resulting in a high starting torque. As the motor rotates, the starting contacts, under the influence of a very light spring, open and place the governor resistor in series with the field. This causes the field current to fall, reducing the armature back emf, increasing armature current and so increasing the speed.

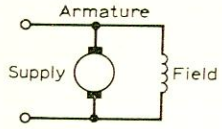


Fig 2.1.
Shunt field motor, basic circuit.

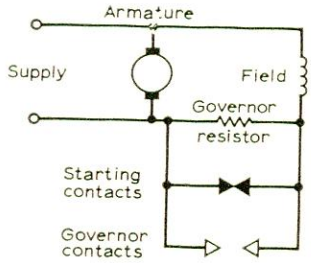


Fig 2.2. Shunt field motor, circuit showing governing arrangement.

When the motor reaches its intended governed speed, which would be rather lower than if the motor were not governed, the governor contacts close due to centrifugal force and so switch the governor resistor out of circuit. When this happens the field current is increased and consequently so is the armature back emf, resulting in lower armature current and a reduction in speed. This in turn allows the governor contacts to open, again placing the resistor in circuit, so increasing the speed. This action is continuous all the time the motor is running and produces a very slight oscillatory motion of the governor contacts. The speed may be held to within $\pm$ 0·5 per cent both for supply variations of approximately 10 per cent and for all the varying loads imposed by the teleprinter mechanism. **Fig 2.3** shows the general arrangement of a shunt field motor governor.

Series Field Motor

The series field motor circuit is shown in **Fig 2.4**. The field and armature windings are in series so that any change in the load will reflect a change in both the armature and field currents. This in turn will produce a flux variation. When the load is light, the motor runs at high speed because the current is low and, therefore, so is the flux. If the load is

increased the speed decreases, resulting in a higher current and, therefore, a higher torque due to the increased flux. It can, therefore, be seen that the starting torque is high. The normal series motor governor circuit is shown in **Fig 2.5**. When the motor is at rest the governor contacts are closed and so short out the governor resistor which is in series with the

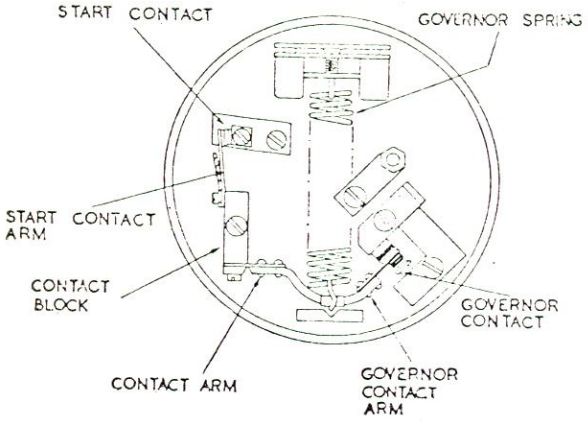


Fig 2.3. Creed shunt field motor governor.

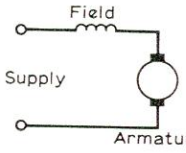


Fig 2.4. Series field motor, basic circuit.

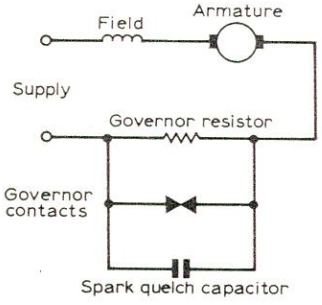


Fig 2.5. Series field motor, circuit showing governing arrangement.

armature and field. As the motor reaches control speed the centrifugal force acting on the contact arm overcomes the tension spring, allowing the contacts to open, and so places the governor resistor in circuit. When this happens the current falls, reducing the torque, and so the speed drops, enabling the governor contacts to make again and increase the speed.

Because the governor has to control an inductive circuit it is essential that spark quenching is fitted to reduce contact wear. **Fig 2.6** shows a typical Creed series motor governor.

Synchronous Motors

Little need be said about synchronous motors. As their speed is determined by the supply mains frequency no governors are required. Also, as no brushes are fitted there are no electrical connections to any moving part, resulting in a motor which requires minimal maintenance.

Maintenance

When used in amateur service the motor is subjected to much less duty than would be encountered in commercial service, but the conditions under which it operates may be much more severe. Because of these conditions, maintenance on the motor, in addition to that of the machine, is essential.

If the motor has greasing points, these should be lubricated with the correct grease at regular intervals. Some motors, especially those used on many Creed machines, require that the ball races be repacked with new grease every 3,600 hours. The old grease should be removed by soaking in white spirit. The races should then be dried thoroughly before repacking with grease, such as Shell Nerita Grease 3. Oil should not be used on ball races unless specified by the manufacturer.

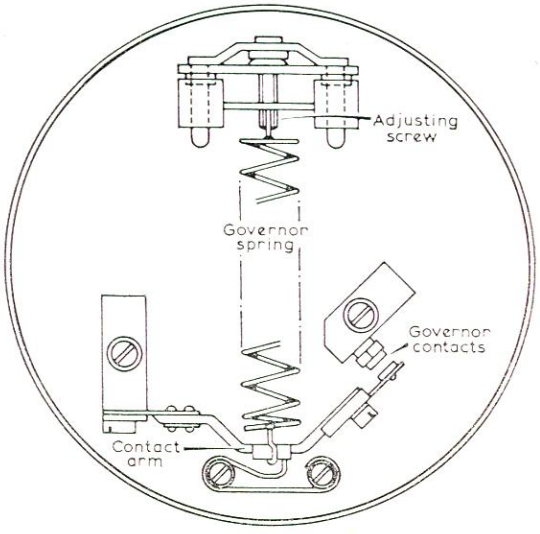


Fig 2.6. Creed series field motor governor.

Brushes should be inspected and replaced if worn down to less than two-thirds of their new length. If the motor has two brush tracks the brushes should be fitted so that they are offset.

Unless the commutator is worn the black deposit on the copper should not be removed. This blackening is an indication of case hardening and its removal will increase wear. If the commutator is worn or grooved it should be skimmed in a lathe using a sharp pointed tool. The mica insulation between the segments should be checked that it is 15 to 25mil below the surface of the commutator. If less than this it should be undercut while the armature is in the lathe by means of a thin square-edge tool.

After skimming and undercutting, the commutator should be polished to as high a degree as possible, as this minimizes brush wear. For polishing, glass paper only should be used. Emery cloth should never be used.

Governor slip rings should be treated in a similar manner to the commutator. Governor contacts should be clean and smooth. If pitted, they may be lightly filed to shape and then burnished with a jeweller's pivot file and burnisher.

ELECTRICAL NOISE SUPPRESSION CIRCUITS

Electrical noise generated by the teleprinter is quite a problem in rtty service. Much attention must be paid to the suppression of commutating and contact signalling circuits, or the operator will find his radio reception is being heavily jammed by his own teleprinter equipment. Even the electrolytic action arising from the rubbing together of many metallic parts in the teleprinter can cause interference if a "hot" aerial wire passes close to the machine. It is essential to get the aerial well away from the telegraph apparatus, and to use coaxial cable for some distance.

A common earth wire to teleprinter and receiver can display standing waves arising from interference noise and cause a great deal of obscure trouble. It is a good idea to provide a direct capacitance earth to the teleprinter by connecting it to a large sheet of metal laid flat on the floor by the shortest possible wire. The metal sheet should also be connected to the mains earth as a safety precaution, but its capacitance to true earth will short-circuit interference voltages that may otherwise get back into the receiver's input via the earthing system. Mains wiring in the vicinity of the equipment should be screened and filtered. Not all teleprinters available to the amateur have suppression devices built in, so a check of these is well worth while.

If motor hash is a problem an improvement may be made by by-passing the motor brushes to earth right at the point at which they are mounted, via a 0·01μF disc ceramic capacitor of 1,000V min working volts. Further improvement may be effected by the use of the small ferrite-cored chokes used for suppression of interference from domestic electrical appliances. These should be placed in each of the motor leads and decoupled on both sides by the special capacitors designed for use with these chokes.

Interference from the telegraph loop must be very carefully investigated before adding suppression components as these will alter the loop time constants and could cause other troubles. Attention should be paid to the condition of the teleprinter keyboard contacts and any polar relay contacts, and if they are at all pitted or tarnished they should be smoothed down and burnished.

CREED MODEL 3 TELEPRINTERS

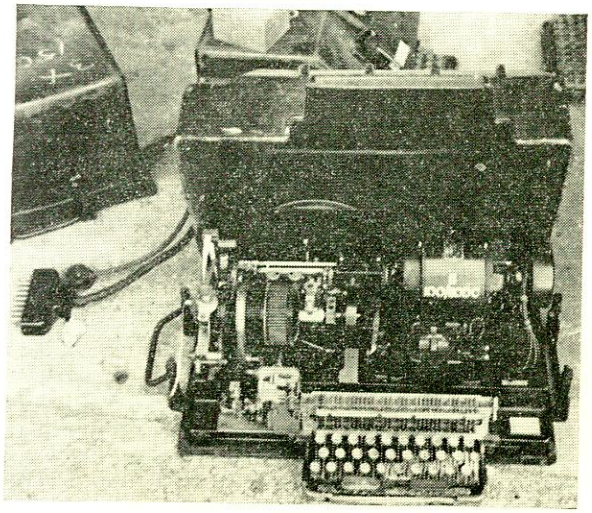
The Model 3 teleprinter was first manufactured in 1927 and was the first Creed machine produced as a combined start-stop transmitter-receiver. It was made to handle public telegram traffic and as such was designed to print out on a gummed paper tape.

Several versions of the Model 3 have been produced, as follows:

3A—Basic type of machine with signalling speed of 49 bauds.
3W—Improved Model 3A, fitted with answer-back mechanism.
3Y and 3Z—Similar to 3W with improved type head clutch and lubrication.
3X—Latest version with general improvements over Model 3Y and 3Z.
3B–3E—Model 3X adapted for 50 baud operation.

The motors fitted were shunt wound dc, 1/27hp and available in four voltage ranges 100/110V, 150/170V, 200/220V and 230/250V. Motor speed was held constant at 2,520rpm by a centrifugal governor.

The machine was different from modern machines in not having a type ribbon. Inking of the types was carried out by two felt rollers which were ink impregnated. They were carried on spring supports so arranged that the rollers pressed lightly on the type faces and rolled over them as the typehead rotated. The platen and associated ratchet were mounted on a bracket which could be swung clear of the typehead to enable cleaning of the types and changing the ink rollers.



The Creed Model 3 teleprinter.

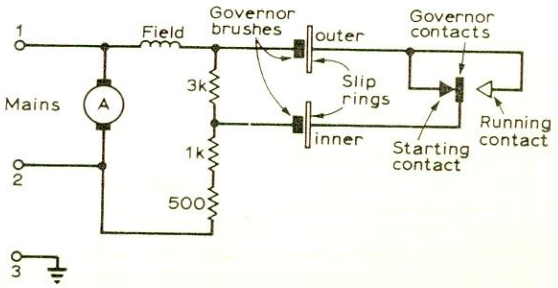


Fig 2.7. Creed Model 3 teleprinter, motor circuit.

All signalling connections were brought out to a 17-way plug, and the power connections to a three-way plug.

The bearings, with the exception of those on the motor, are plain and consequently require fairly frequent lubrication.

LUBRICATION CHART FOR TELEPRINTER TYPE 3

Lubrication	Amount
Oil well in receiver cam shaft bearing (motor end)	Few drops
Two lubricators or oil wells on main bearing bracket	Half full
Oil well in typehead spindle bearing	Few drops
Lubricator on receiving cam shaft bearing (typehead end)	Half full
Lubricator for transmitter driving shaft	Half full
Oil well for transmitter ratchet shaft (front)	Fill
Clutch spring typehead No 2	Few drops
Oil hole in type carriage cf typehead	Few drops
Oil hole in bellcrank lifting collar	One drop
Oil hole in bellcrank lifting lever spindle	One drop
Receiving cam tracks and rollers	One drop
Finger setting blade guides	One drop
Comb setting fingers	One drop
Feed lever spindle	One drop
Trip bellcrank spindle front	One drop
Trip bellcrank spindle rear	One drop
Selecting levers and transmitting cam tracks	One drop
Oil hole for Answer-back gear wheel No 3 spindle	Few drops
Oil holes in combination bar resetting lever	One drop
Oil hole for Answer-back spindle rear	Few drops
Oil well for Answer-back spindle front	Fill
Retention lever spindle	One drop
Tube for locking bar No 2 bearing left	One drop
Oil hole in locking bar No 2 bearing right	One drop
Oil hole for comb setting lever	One drop
Typehead clutch	Grease
Contact lever bearings	One drop
Combination bar guides	One drop
Key bar rollers	One drop
Finger setting bellcrank	One drop
Platen spindle	One drop
Typehead clutch should be well greased when re-assembled after overhaul	

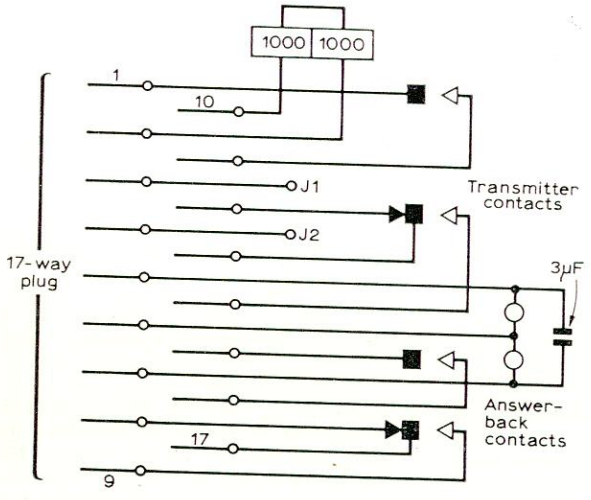


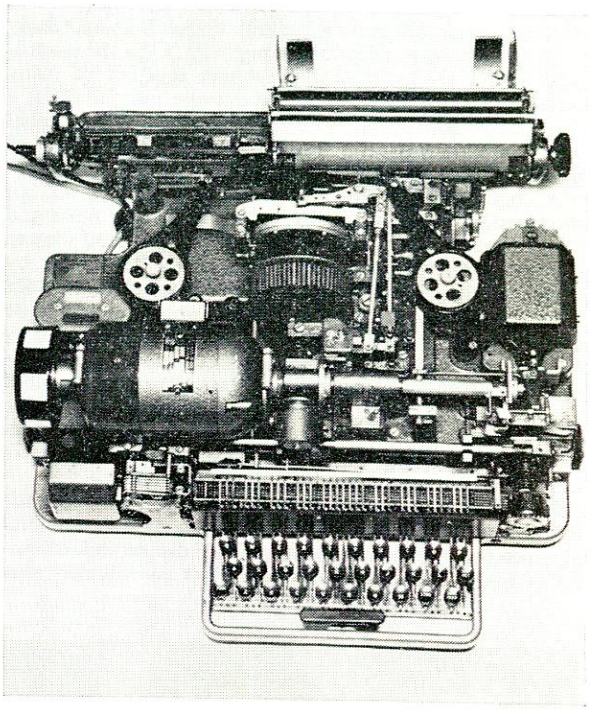
Fig 2.8. Creed Model 3 teleprinter, signal circuit.

THE CREED 7B

Introduction

The Creed 7B teleprinter, which has been released in large quantities during the past few years, is on the face of it a complex machine. However, it can be sub-divided into easily appreciated assemblies.

The essential functions of a teleprinter, not only the 7B, are to originate and receive the mark-space combinations. Much useful information can be obtained by turning the motor by hand while operating the electromagnet and the keys and watching the ensuing motions. Do not turn the motor backwards and do not force anything.



The Creed Model 7B teleprinter.

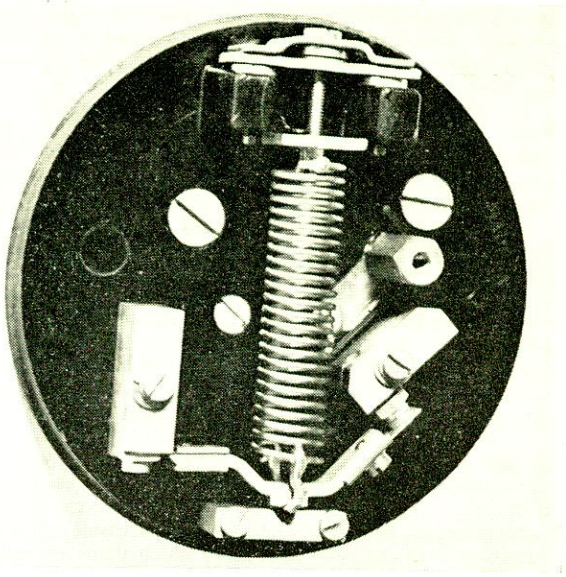
Speed Adjustment

Correct governed speed of the motor is the first requirement. Early teleprinters have a large white spot painted on the typehead spindle gear wheel, just above the keyboard and facing the operator. This rotates quite slowly. A stroboscope consisting of a shutter mounted on a reed which may be made to vibrate at its resonant frequency, so opening and closing the shutter, is used to view the spot. If it appears stationary, speed is correct, but if the spot appears to move clockwise or anti-clockwise the speed is fast or slow respectively. When the speed discrepancy is large, this is a difficult and frustrating device to use. Modern teleprinters running at 50 bauds have five equal white spots painted around the circumference of the governor cover, and these are viewed through a shutter consisting of two light plates mounted at the tips of the arms of a 125Hz tuning fork. Each plate has a slot in line with the fork arms, and as the fork oscillates

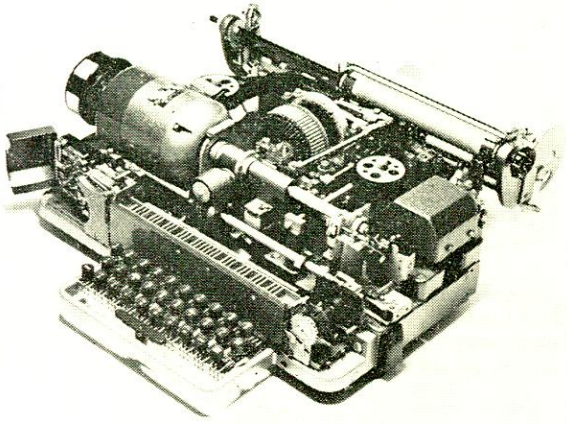
the slots become briefly coincident at the resonant frequency of the fork.

If the amateur's machine is of the type first described, it is recommended that a strip of white paper ½in wide be cut to the exact length of the governor circumference, and divided into 10 equal parts, five of which are coloured black. This can then be stuck around the governor with a powerful adhesive.

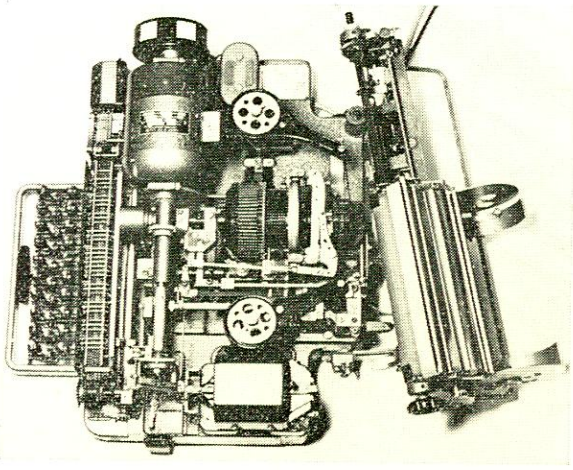
For 45·5 baud operation, there should be 11 black, 11 white spots when used with a 125Hz tuning fork. A cheaper and more readily obtainable indicator than the 125Hz fork can be made by constructing an oscillator checked against 50Hz mains frequency with an oscilloscope, and using its output to drive a small neon lamp. When the neon is held near the governor cover in semi-darkness the white divisions will appear stationary if speed is correct, or move slowly in the direction of the motor rotation if speed is fast, and vice versa.



Creed series motor governor.



The Creed Model 7B without orientation device.



The Creed Model 7B with carriage swung back to the stops. The carriage may now be removed by simply lifting off.

The speed of a newly acquired machine may be quite a long way out, in which case it may be outside the range of the stroboscope. It is possible to find a false speed setting which holds the spots steady due to some harmonic relationship with the correct speed. Setting the speed approximately correct can be done by counting the number of characters printed in a measured time, with the teleprinter continuously transmitting one character. To do this, press one character key and hold it down, at the same time pushing up the keyboard clutch pawl abutment so that the clutch cannot latch. Sixty characters can be printed in a single line on a page teleprinter, and since each takes 150ms, 60 will take 9s.

The receiving and sending mechanisms both operate from the same motor and will therefore always be in synchronism with each other, irrespective of actual speed. A speed fault will not show up as mutilations on the local record printed.

Speed adjustment is made by removing the governor cover, which is held by a single screw. Increasing the centrifugal spring tension by the tensioning screw at its end increases speed, or slackening it decreases speed. The condition of the governor contacts is important, both from the point of view of smooth control and radio interference. If pitted they should be rubbed flat with fine glass paper.

The Transmitting Mechanism

The principle of operation from the keyboard is illustrated in **Fig 2.9**. There are five combination bars (CB), one for each element in a character. These bars have a series of projections along their upper edges arranged so that, if a character key is pressed, the keybar (K) associated with it will impede movement to the right of such combination

bars as have projections at that point. The combination bars are each spring-loaded towards the right, but are held against the springs by the common returning lever (RL) while the keyboard is at rest.

The vertical member of each keybar has a projection which forces down the trip bar (TB) as soon as a key is pressed, and this causes the trip lever (TL) to move in a clockwise direction, so lifting the pawl abutment out of engagement with the one-revolution clutch pawl (P).

The one-revolution clutch is shown in **Fig 2.10**, and its purpose is to provide one rotation of the transmitting cam shaft (TC) whenever a key is pressed. Its latching action prevents a second rotation in the event that the key is held down longer than the time taken to transmit the character. Operation of the keybar (b) forces down the trip bar (a) and the bell-crank (c) moves in a clockwise direction, causing the pawl abutment (d) to move in an anti-clockwise direction, so raising its tip out of engagement with the pawl (e). The pawl therefore drops down under the pressure of its spring and engages a tooth on the ratchet wheel, which is continuously rotating under motor drive. This causes the cam shaft to rotate. In rotating, the cam (f) forces the link (g) between the bell crank and the pawl abutment out of engagement with the pawl abutment, which therefore moves back into position to arrest and trip the pawl out of engagement with the ratchet when the single revolution has been completed. If the key is held down after this time, the pawl abutment will not again release the pawl because the link remains out of engagement, and will not re-engage the pawl abutment until the trip bar has been released by the raising of the keybar when the character key is released from pressure by the operator.

Reverting to **Fig 2.9** when the camshaft starts to rotate, the common returning lever (RL) is allowed to move in an anti-clockwise direction on its spindle by the profile of its cam (C), thus releasing the combination bars, which can then move to the right under their spring tensions. Due to the projections on the combination bars, some will move freely, while others will be arrested by the keybar, according to which key has been pressed. The combination bars therefore set up the character combination by their relative positions. The process which follows is that of transforming this simultaneous condition of five elements into a sequential string of signals on the single wire output from the transmit tongue contact.

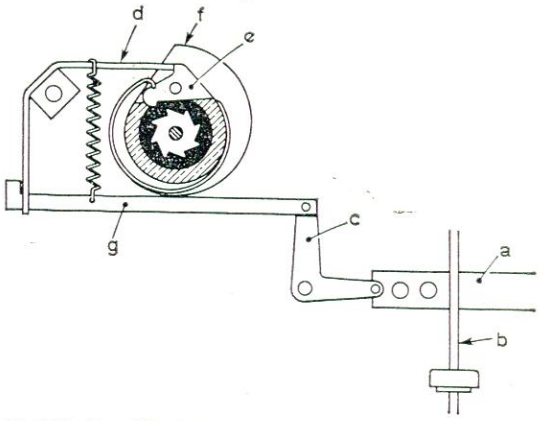


Fig 2.10. Creed Model 7 teleprinter, one revolution clutch.

As the cam shaft rotates, the shape of the front cam on the shaft forces up the start-stop lever (SSL), which allows the common operating lever (CL) to move in a clockwise direction on its spindle under the tension of its spring (TCS).

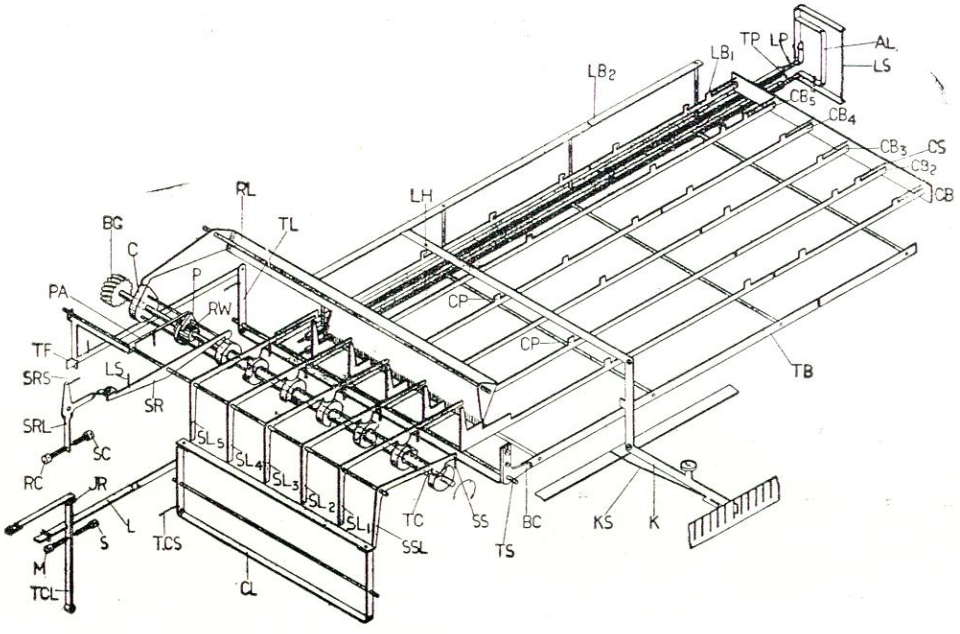


Fig 2.9. Creed Model 7 teleprinter, transmitting mechanism.

The link (L) moves to the right and pulls over the transmit contact tongue (TCL) to space, thus sending a start signal. The tongue has a jockey roller (JR) giving a toggle action to the contact, which improves its transit time and provides a firm contact pressure.

Each of the element cams has a dimple in its profile, and these dimples are staggered in relation with each other. When the dimple on the first cam becomes coincident with the projection on the first selector lever (SL1), this lever will drop under its spring tension, provided the combination bar has moved to the right so that its tip does not impede the movement of the selecting lever. Dropping of the selector lever will force the common operating lever to move in an anti-clockwise direction on its spindle, and its link will switch the tongue contact to mark. If the selector lever is prevented from dropping by its combination bar, the contact will remain at space.

This process is repeated for each element in turn, as their individual cams offer movement to the selector levers. After the combination has been transmitted, the front cam profile again allows the start-stop lever to drop, so forcing the common operating lever to mark for the stop signal. The clutch latches at the completion of one revolution, and the cam at the rear end of shaft causes the common returning lever (RL) to reset the combination bars.

There are two locking bars associated with the keyboard. The first (LB1) moves and locks the keybar as soon as a character key has been pressed, so that the key will remain operated for the duration of the character transmission, irrespective of when the operator removes his finger from the key. The second (LB2) moves forward when a key is pressed and takes up position between the operated keybar and all the others, thus preventing operation of a second key while a character is being transmitted. A fast typist can feel the action of this locking bar holding back the speed of typing.

The modern "N" series keyboards differ from the type described above. They are available with three or four rows of character keys. In the latter case figures are on a separate row, just like a typewriter keyboard, and an interlocking arrangement prevents a key in either upper or lower shift case being pressed unless the appropriate shift key has been pressed previously.

The Selection and Printing Mechanism

Fig 2.11 illustrates the selection and printing mechanism. The movement of the armature extension of the receiving magnet (RA) causes the trip shaft (TS) to move on its spindle, clockwise for a space and anti-clockwise for a mark. The trip shaft is linked to the pawl abutment (D) of the receiving cam clutch, which works in rather a similar manner to the transmitter clutch. The first space received trips the pawl and the cam makes one revolution.

The striker blade (SB), which is a thin steel spring leaf, is arranged to oscillate in the horizontal plane by the movement of the finger setting lever (STL) running in cam slot T1. At the same time a vertical oscillatory movement is imparted to the striker blade by the movement of the trip shaft, which is

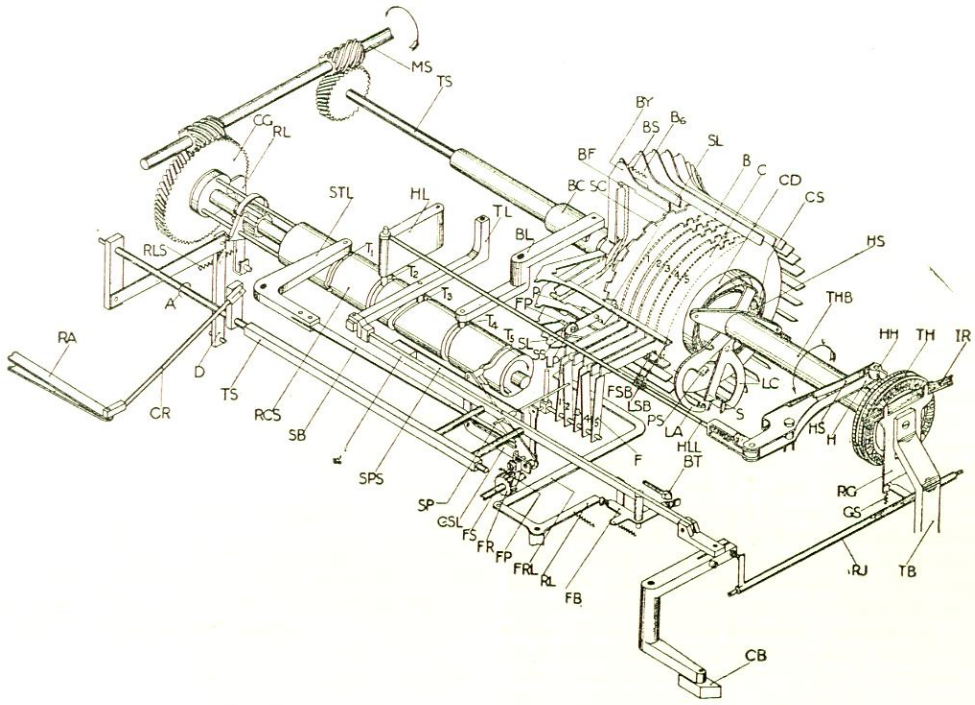


Fig 2.11. Model 7 teleprinter, selection and printing mechanism.

under control of the magnet, and whose movement thus follows the marks and spaces of the character combination being received. The striker pin (SP) is held in position by the traversing link (L), and the latter is driven by the traversing lever (TL), running in cam slot T3, which causes the link to move parallel to the trip shaft, carrying the striker pin with it. The timing of the traversing link, relative to the striker blade, is such that the striker pin is in line with one of the selector fingers (F1 to F5) every time the striker blade moves towards it. If the striker blade is in the upper position of its vertical plane movement, occasioned by a mark, the edge of the blade will strike the striker pin and move it forward, thus pushing back the coincident selector finger. When a space is being received, the striker blade will be in its lower position and will pass beneath the striker pin, so that the coincident selector finger will not move. In this manner the combination of the character is recorded on the positions taken up by the selector fingers.

So far the operation of the mechanism has reached the stage of converting the sequential movements of the magnet armature into five steady state conditions of the selector fingers. The next step is to convert these five separate conditions into one of the 32 possible conditions which together they provide. This is done by the translating mechanism. Five combination discs (C1 to C5) are mounted in an assembly, each able to move radially. Around their peripheries are a series of slots, and around the assembly are grouped 64 bellcranks (B), each tensioned by its own spring (BS) towards the assembly. The combination disc setting lever (CSL) is driven from slot T5 in the cam, and raises the spindle on which the five selector fingers pivot, after all the fingers have been set to the combination. Simultaneously the bellcrank lifting lever (BL), operating from cam slot T4, pushes the sliding sleeve (BC) up against the bottom ends of the bellcranks, lifting them and so freeing the combination discs from their pressure. The combination discs are spring-loaded and will rotate if their extension arms are not impeded by the selector fingers. Those selector fingers which have been pushed back by the striker pin into the mark position will obstruct the combination disc movement, while those which are in space position will be clear of the combination disc extensions, and those discs will move. For any combination there will always be one channel formed by a slot in each combination disc in line with all the others, allowing one of a pair of adjacent bellcranks (upper and lower case of the character) to drop into the channel so formed. A disc mounted at one end of the combination disc assembly and slotted regularly about its periphery (SC), is set in one of two positions by either the letter-shift bellcrank (LSB) or the figure-shift bellcrank (FSB), and the positioning of its slots determines which one of the character bellcranks will drop into the channel formed by the combination discs.

At the time the bellcranks are lifted by the sleeve (BC), the typehead clutch is engaged. This is a friction device which drives the typehead round until it is stopped by the position of the selected bellcrank. In this position, the character set up by the combination is presented to the type hammer (HH) ready for printing. By this time, however, the cam has almost completed its full revolution, and the actual striking of the type by the hammer, initiated by cam slot T2, takes place during the next selection process just before the bellcranks are lifted for setting of the combination discs. Consequently the printing is always one character behind the transmission.

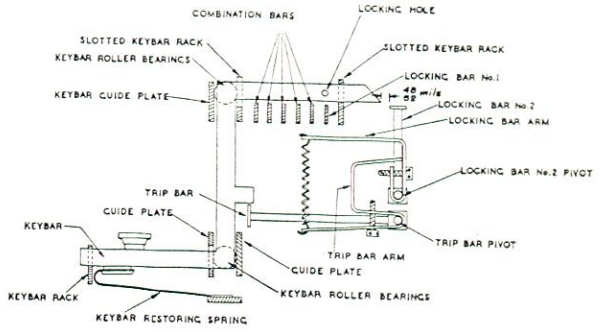


Fig 2.12. Keybar locking mechanism.

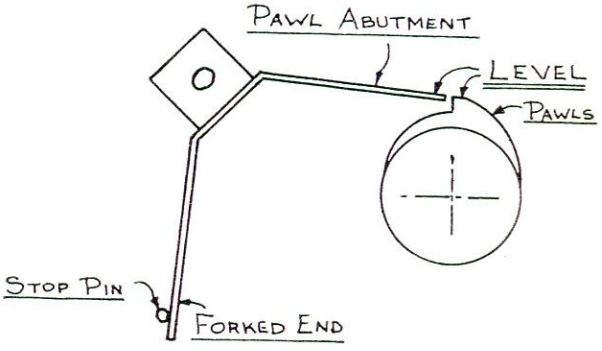


Fig 2.13. Transmitter pawl abutment.

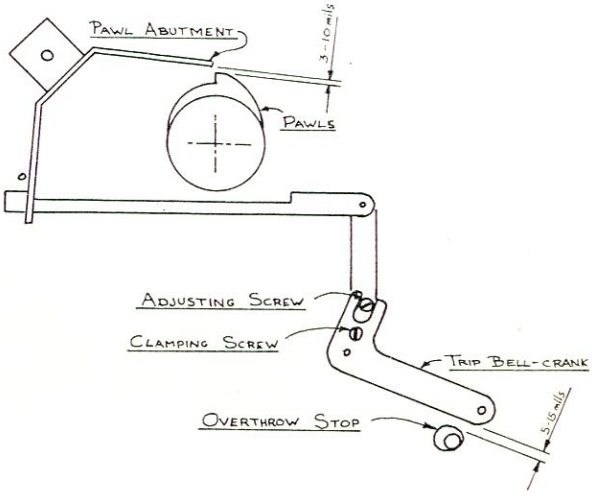


Fig 2.14. Transmitter pawl abutment.

Letter feed of the page carriage is accomplished by the action of the feed lever (CB), driven by the traversing link (L). Combinations resulting from letter-shift, figure-shift, carriage-return, upper case of J (bell) or all spaces, must not cause the carriage to feed. The bellcranks proper to these functions operate control levers, all of which operate a common non-feed lever, which inhibits operation of the feed mechanism for such non-printing combinations.

A pawl (FP), mounted at one end of the combination disc setting lever (CSL), steps a ratchet wheel (FR) to provide the feeding action of the inked ribbon.

Mechanical Construction

The 7B is unit-built, that is, there are several units which can be taken off the main base casting and treated as self contained units. These units have locating abutments, frequently painted red (P.O. machines may have yellow ones), which should not be adjusted as they have been accurately set in the factory in a jig.

Brief instructions are given for the removal of the units that present some special trick or difficulty. Those not mentioned can be removed in a straightforward way. These instructions are included so that the units can be removed for cleaning, if necessary. In order to adjust the machine no units need be removed. Further instructions for dismantling the units are not included, being out of the scope of this chapter. In most cases the units are simply built up and should be easily dismantled if necessary.

When the machine is completely reassembled, all abutment screws must touch their fellows and the cam unit casting must abut against the rear bearing block of the combination head. Further, no fixing screws should be tightened unless the unit they are securing is seated firmly and squarely on the base. If any unit casting is felt to give, it indicates that the unit is not seated properly.

Remove Keyboard Unit

Support keyboard and remove the two fixing screws. Remove by pulling straight forward—not bending the contacts.

Remove Transmitting Unit

Remove transmitting contact block, by removing screws at top R.H. and bottom L.H. Depress letter shift key, rotate transmitting cam to allow combination bars to clear the resetting lever. Remove transmitting unit fixing screws. Tilt unit forward to disengage trip bellcrank from keyboard trip bar. Pull unit to the left, raising it slightly clearing the resetting lever from the combination bars—turn it back to vertical, pulling to left till the driving shaft is drawn out of the ballrace.

Remove Motor

Remove governor. Withdraw the fixing screws of the L.H. end plate. Lift L.H. end of motor and slide to the left, minding the governor brush springs.

Remove Typehead

Remove screw securing the typehead bearing bracket to the control lever casting—draw the bracket clear of pin—raise it and draw clear of ribbon jumper. Draw typehead off driving pins.

Remove Control-Lever Unit

Turn the safety catch to hold control levers away from bellcranks. Remove two fixing screws—lift unit and remove, watching the "J"-bell contact rod.

Remove Receiving Cam Unit

Remove electromagnet bias spring (if fitted) and the electromagnet link from the electromagnet, lift ribbon feed pawl over dead centre. Remove receiving cam unit fixing screws and carefully remove unit.

Remove Combination Head

Remove main shaft and starter switch control unit. Withdraw dowel pin from keyboard and bearing, remove that fixing screw and those fixing the strap at the other end. Hold back answer back release shaft from the bellcranks—remove. Do not adjust eccentric screw on L.H. side.

Mechanical Adjustments

All the necessary adjustments can be carried out with the minimum of special tools. Those that are essential are: a set of BA spanners, a screwdriver, a set of feeler gauges—preferably small ones—and a tension gauge, say up to 1lb.

Before starting to work with the tool kit on the 7B it is well worth while sitting back and considering just what is wanted. Most machines are in reasonably good condition when obtained; however if a complete overhaul, clean and adjustment is needed it would be better to find a comprehensive manual that covers all the necessary details.

Keyboard Locking Bar No. 2

Slacken the trip bar arm clamping screw and, while holding the trip bellcrank fully anti-clockwise, adjust the trip bar arm to give a clearance of 5–6mil between the locking bar arm and the forked back stop. See **Fig 2.12.**

Slacken the locking bar arm clamping screw, and, with the keybars in the up position, adjust the locking bar arm to give a clearance of 48–52mil between the keybar extensions and the locking bar No. 2. Tighten both clamping screws. See **Fig 2.12.**

Transmitter Pawl Abutment

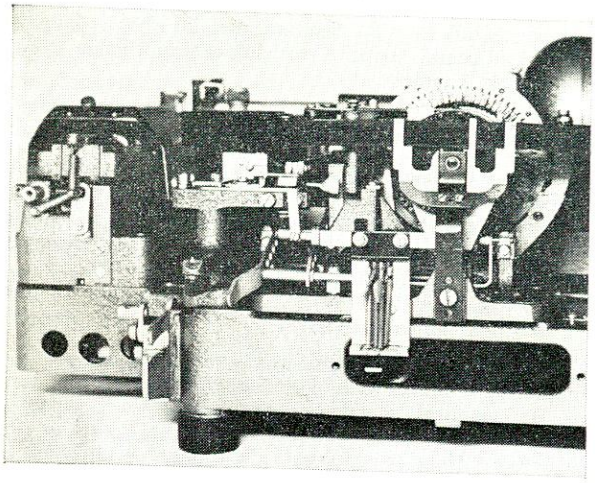
To make the pawl abutment level with the top of the pawls, when the forked end is touching the stop pin, slightly bend the forked end. See **Fig 2.13.**

Depress a key and turn the motor slightly manually. Slacken the trip bellcrank clamping screw and adjust the eccentric adjusting screw until a clearance of 3–20mil between the pawl abutment and the pawls is obtained. Tighten the clamping screw. See **Fig 2.14.**

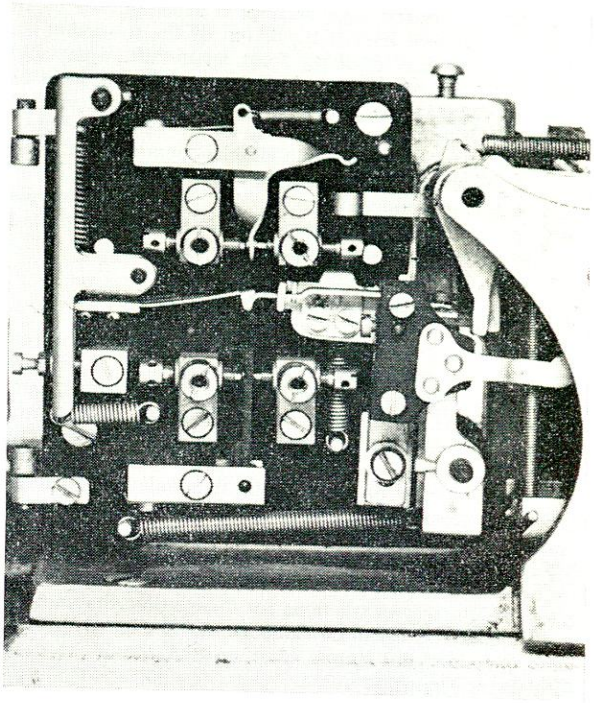
Slacken the overthrow stop clamping screw and adjust the knurled overthrow stop to give a clearance of 16–50mil between the overthrow stop and the trip bellcrank when a keybar has been operated.

THE CREED MODEL 7B TELEPRINTER

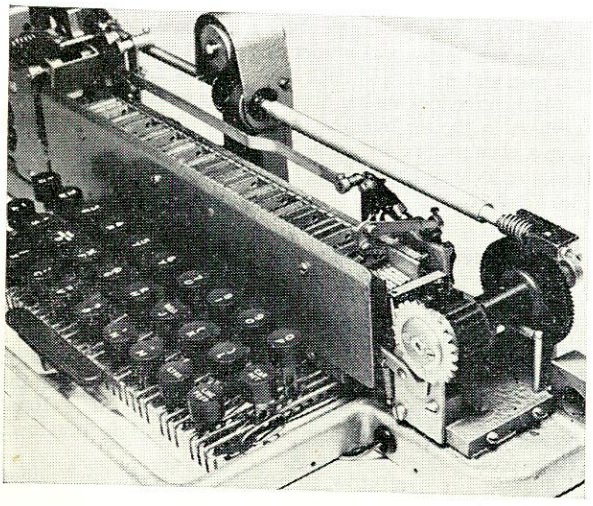
Design and construction details



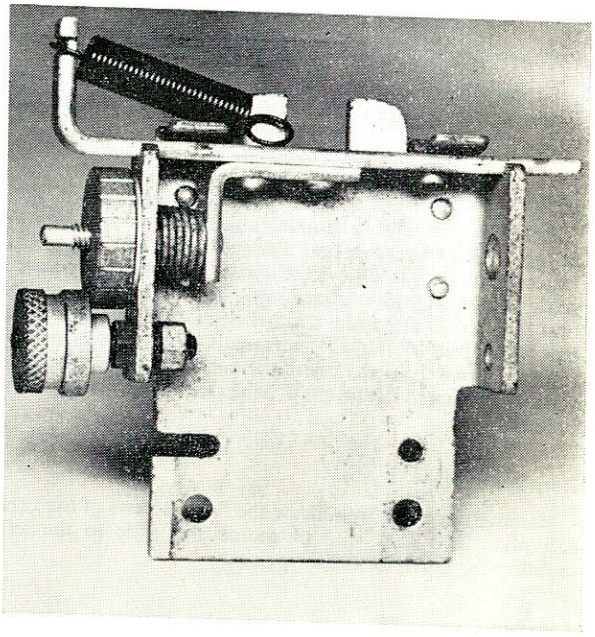
The Creed Model 7B teleprinter, rear view with carriage removed showing letter feed lever, feed throwout lever and carriage return and line feed levers.



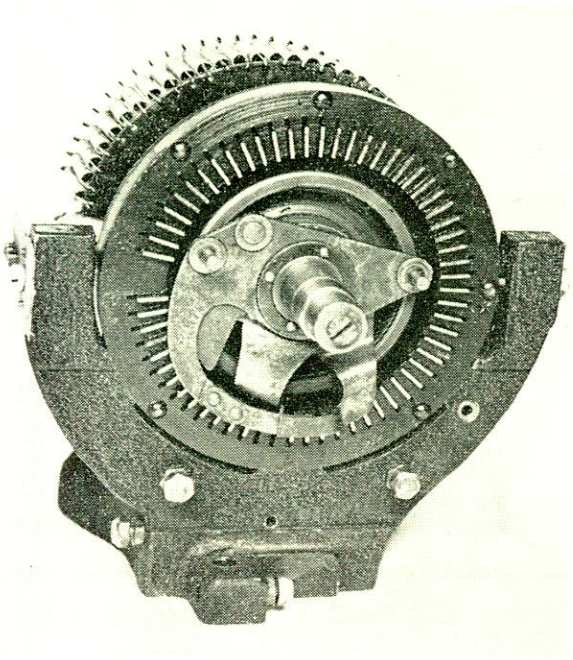
The 7B transmitter assembly.



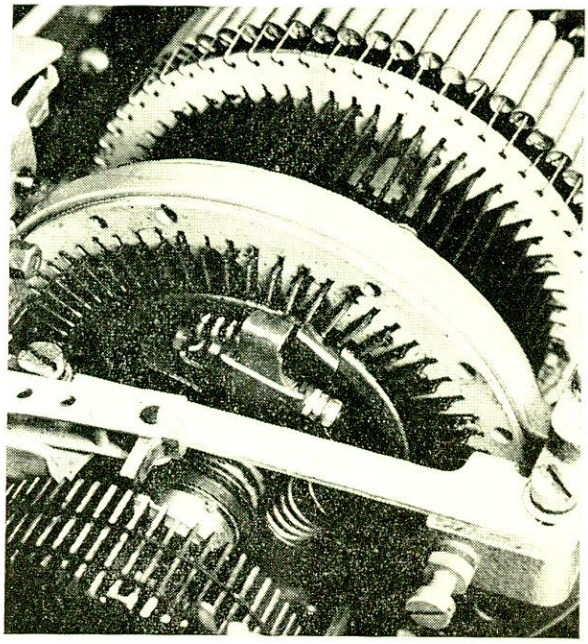
The Creed character counter fitted keyboard, showing long counter lever and the short resetting lever. At right front is the answer-back drum.



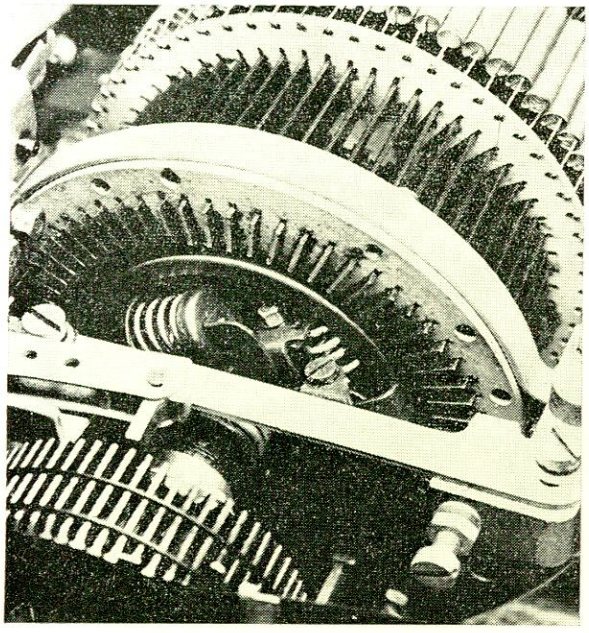
Creed 7B single current bias spring and mounting bracket.



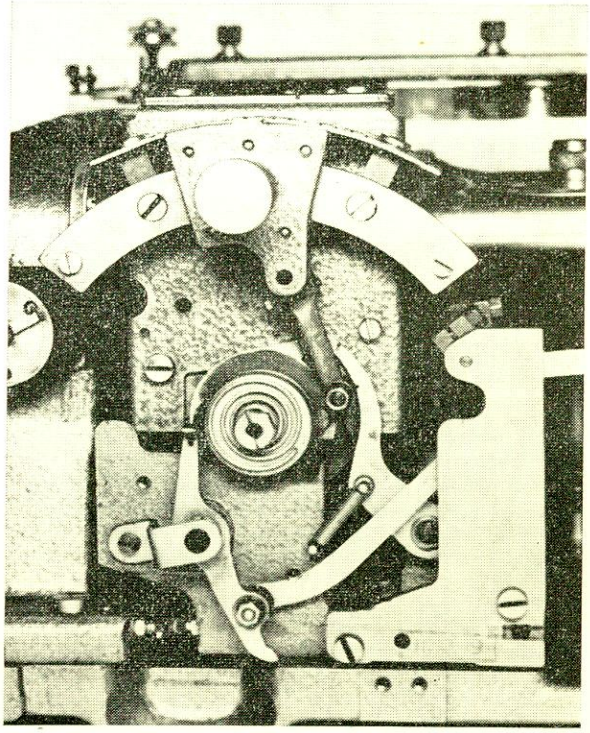
The Creed 7B older pattern typehead clutch.



The 7B typehead clutch, later version, showing latches.



The Creed 7B typehead, later version showing damper springs.



Creed orientation device as fitted to a 7B teleprinter.

Resetting Lever

With motor running, slacken the re-setting lever spindle clamping screw and adjust by turning the eccentric spindle to give a clearance of 6–20mil between a combination bar projection and a keybar extension. Tighten clamping screw. See **Fig 2.15**.

Transmitter Contacts (Striker Type)

The striker type was introduced in 1939 and produces a less distorted signal than the previous type. For a general view of the striker mechanism see **Fig 2.16**.

Depress a key and turn motor manually until the striker timing lever is riding on a crest of the timing cam. Slacken the striker timing lever assembly block fixing screw, **Fig 2.17**, and adjust the clearance between the striker and transmitting tongue knife edges, when directly in line, to 15mil. Tighten the fixing screw.

Manually turn the motor until the third and fourth selecting levers are both touching the insulated edge of the contact operating lever. To check, push the bottom of the contact operating lever to the left and note if both the select-

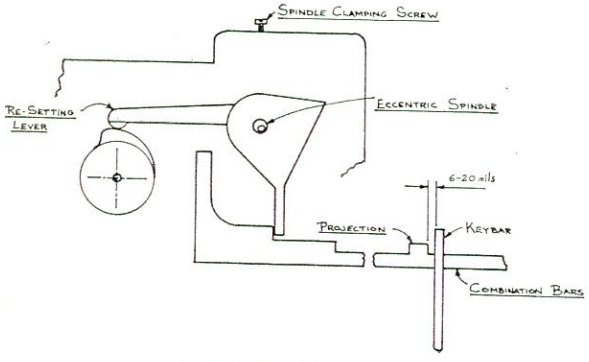


Fig 2.15. Resetting lever.

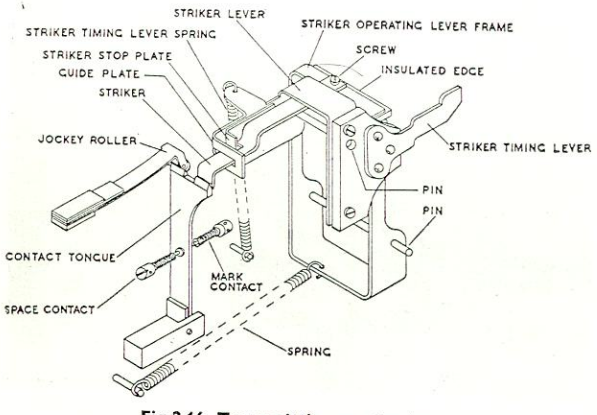
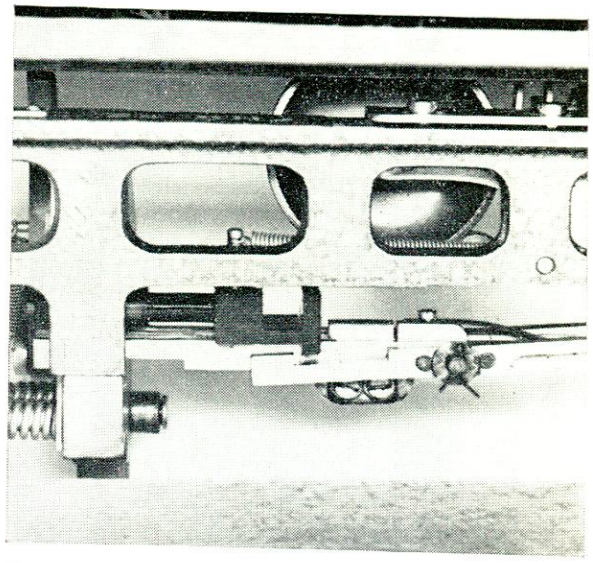
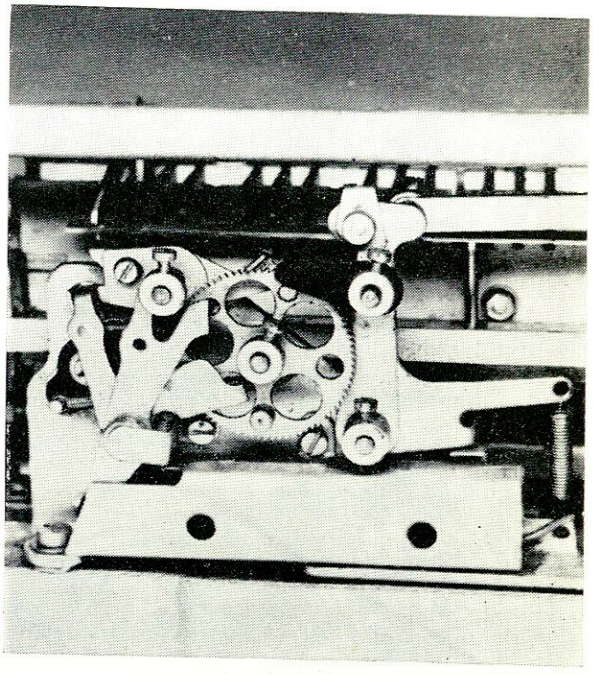


Fig 2.16. Transmitting mechanism.

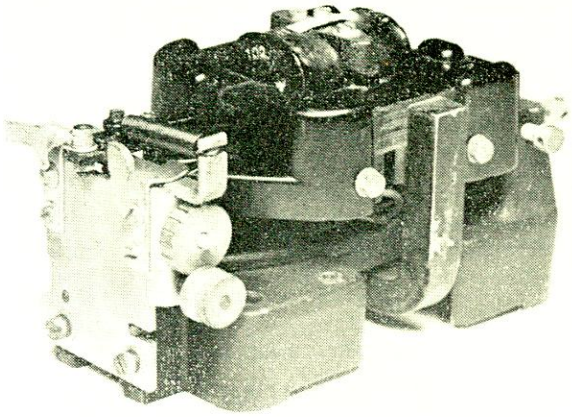


The Creed Model 7 teleprinter carriage showing letter feed dog and crosshead.

CREED MODEL 7 DETAIL

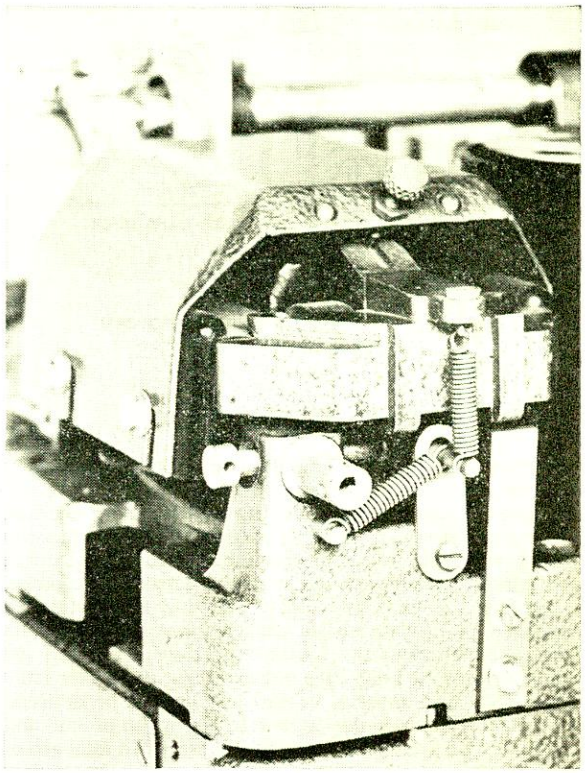


Character counter as fitted to some keyboards on Creed models 7 and 85R.

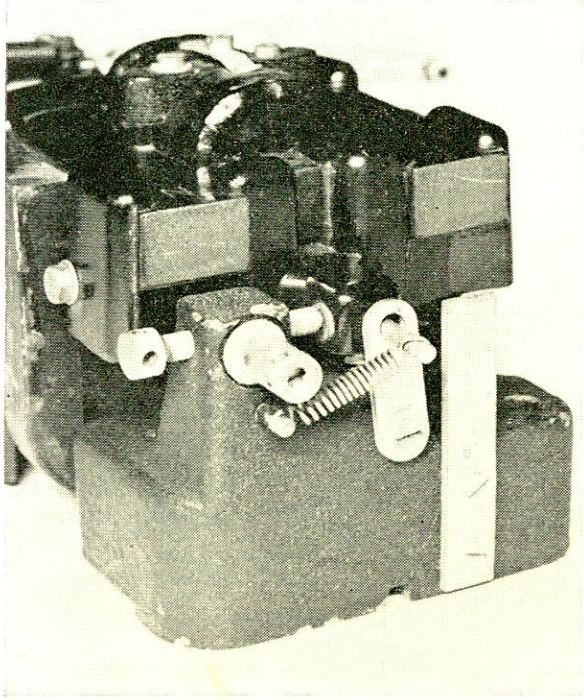


Model 7B teleprinter electromagnet showing single current bias spring adjuster.

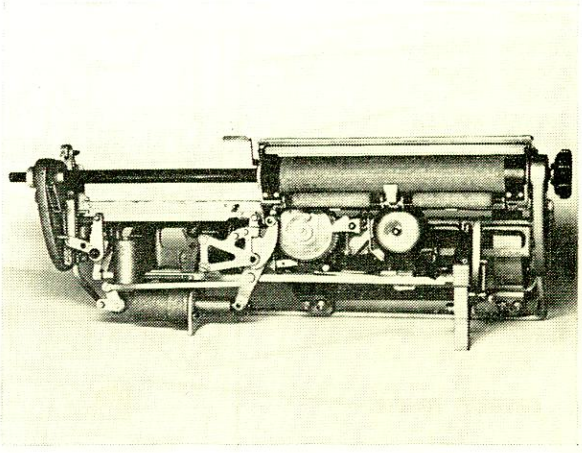
CREED MODEL 7 DETAIL



The 7B later type electromagnet, showing adjustment screws.



The 7B electromagnet, rear view, showing adjusting screws.



The Creed 7B teleprinter carriage, front view, showing air damper cylinder, return spring drum and bell.

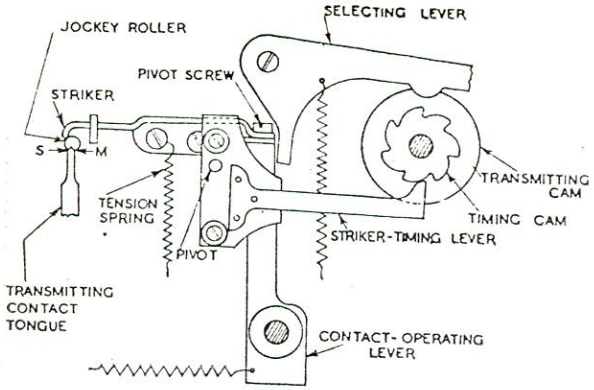


Fig 2.17. Striker timing lever.

ing levers move the same amount in an upward direction. If they do not, repeat until correct. Insert a 15mil feeler gauge between the selecting levers and this insulated edge. Slacken the two striker stop plate fixing screws and position the stop plate so that it just touches against the R.H. edge of the slot in the striker. Tighten the fixing screws and remove the gauge.

Keeping the third and fourth selecting levers still just touching the insulated edge, slacken the contact clamping screws. Now clamp the transmitting tongue between the contacts, with the knife edge directly under the striker knife edge. This adjustment is critical and should be adjusted accurately. Withdraw one contact to give a gap of 3mil and clamp. Withdraw the other contact 3mil to give a total gap of 6mil. Tighten the clamping screws. The striker should now ride down each side of the transmitting tongue knife edge to an equal amount, when the motor is turned and the "Y" keybar depressed.

The jockey frame bias screw locknut (or clamping screws) is slackened and the bias adjusting screw is adjusted to give equal force, $4\frac{1}{4}$–$4\frac{1}{2}$oz, between the transmitting tongue and both contacts. Tighten the locknut (or clamping screws). See **Fig 2.18a**. **Fig 2.18b** shows the general layout of the complete transmitter.

With the striker at its maximum height the force to lift it further should be $4\frac{1}{2}$–$5\frac{1}{2}$oz. There is no adjustment for this; if the value is outside the limits this shows that the spring needs changing.

With the Rx/Tx switch resting on the Rx contact and with the motor running there should be 3mil clearance between the ebonite stud and the switch blade, with a gap between the Tx contact and the switch blade contact of 6mil. See **Fig 2.19**.

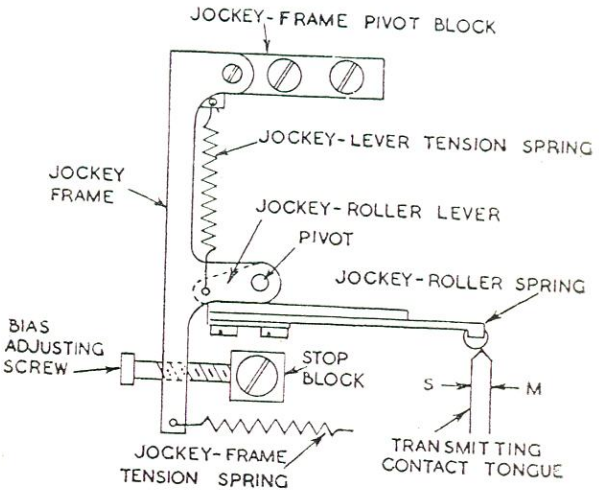
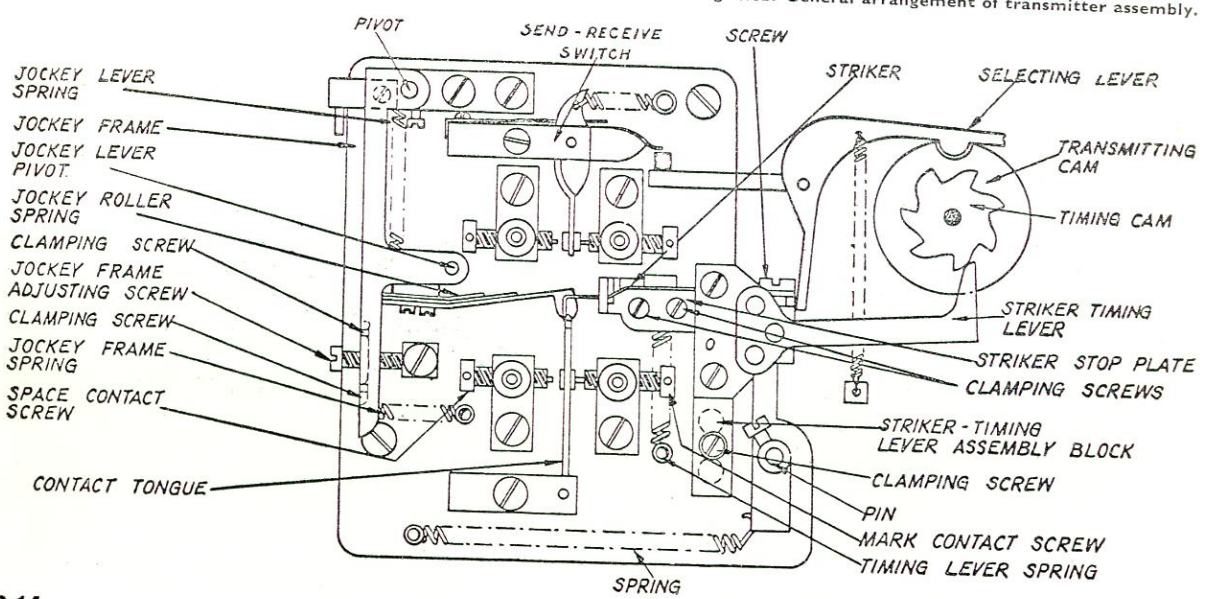


Fig 2.18a. Jockey roller.

Below: Fig 2.18b. General arrangement of transmitter assembly.



Receiving Side: The Electromagnet

The electromagnet armature should have a travel of 22–25mil measured at the stop plates. See **Fig 2.20**.

Remove the electromagnet link, slacken the bias adjusting screw clamp screw and adjust the bias adjusting screw, situated at the rear of the electromagnet, until the forces to move the armature in both directions are equal and between 8–12oz. Tighten clamping screw. Replace electromagnet link.

If an accurate tension gauge is not available it is possible to set the bias correctly by measuring the current necessary to throw the electromagnet armature in both directions, and adjusting the screw to obtain equal readings.

Electromagnet Mk II

This electromagnet can be adjusted off the machine and can be identified by the armature stop plate which is secured to the electromagnet casting.

The Finger-setting Blade

Move the electromagnet armature to space (RHS), rotate the motor manually, returning the electromagnet armature to mark (LHS), until the blade just touches the finger-setting pin, when this is opposite the central finger. Slacken the trip shaft lever clamping screw and, holding the electromagnet armature against the mark (LHS) stop, rotate the trip shaft until the finger-setting blade strikes the centre of the finger-setting pin. Tighten the clamping screw. See **Fig 2.21**. If this is adjusted then the receiving cam pawl adjustment must be checked.

Rotate motor manually and by moving the electromagnet armature to the mark (LHS) position set up LTR shift (MMMMM). The distance between the 5th finger and the slotted stop plate, or the resetting link if this is closer, should be 2–5mil. To adjust—release the finger-setting blade clamping screw and adjust the position of the blade, so that when the motor is again turned the above condition is met. Tighten the clamping screw. See **Fig 2.22**.

Rotate the motor until the receiving cam pawls are clear of the abutment and the finger-setting blade is clear of the finger-setting pin. Check that the forces to move the electromagnet armature in both directions are within 2oz of the figure obtained without the electromagnet link connected. They should also be within $\frac{1}{4}$oz of each other. To obtain neutrality the finger-setting blade is given a set by careful stroking. The blade can easily be removed by removing the two screws on the blade guide and removing the top plate. See **Fig 2.22.** The blade and its bellcrank can then be lifted off its pivot, after removing pivot retaining screw. Beware that the roller follower does not drop off the small pin at the end of the bellcrank.

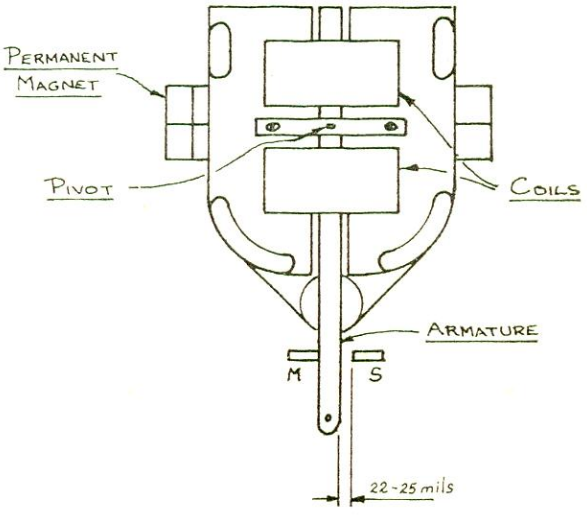


Fig 2.20. Receiving electromagnet.

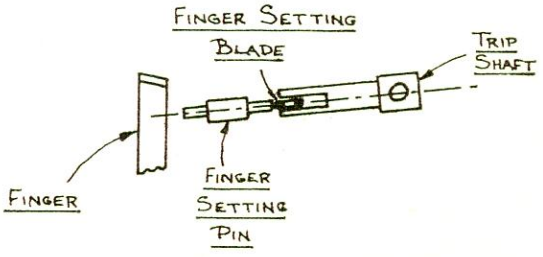


Fig 2.21. Finger-setting blade, height setting.

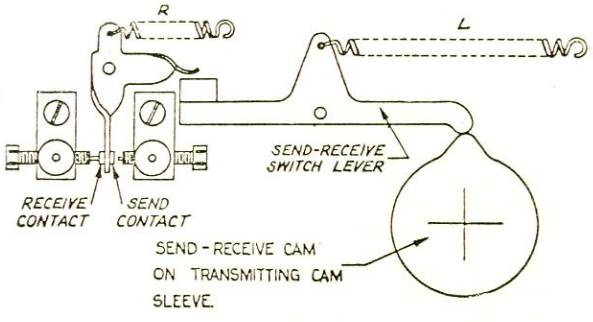


Fig 2.19. Send-receive switch.

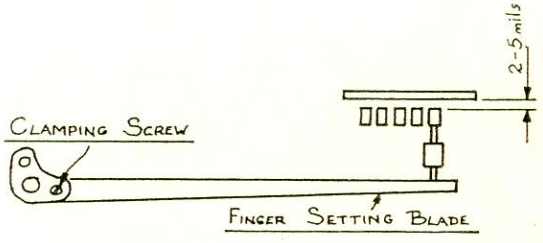


Fig 2.22. Finger-setting blade, height setting.

The Receiving Cam

The receiving cam bearings need very critical adjustment as the maximum end play allowable is 1·5mil. However, there must be no initial end loading of the bearings. To adjust—slacken the rear bearing screw clamping screw and adjust the rear bearing screw until the above conditions are fulfilled. Tighten the clamping screw securely after adjustment.

Rotate the motor manually, with the electromagnet armature in the mark (LHS) position, until the receiving cam is arrested, with the retention lever fully embedded in its recess. The force to move the pawls away from the pawl abutment should be $2\frac{1}{2}$–$3\frac{1}{2}$oz. The gap behind the pawls is adjusted to 3mil by slackening the retention pivot locking nut and rotating the eccentric pivot. Tighten locknut. See **Fig 2.23.**

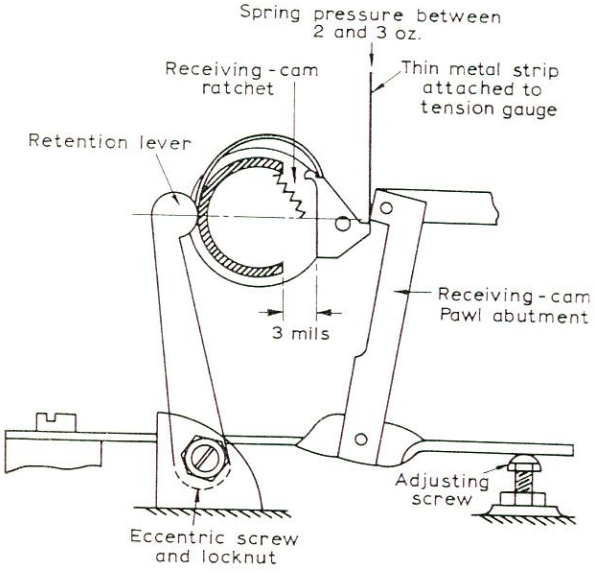


Fig 2.23. Receiving cam pawl abutment.

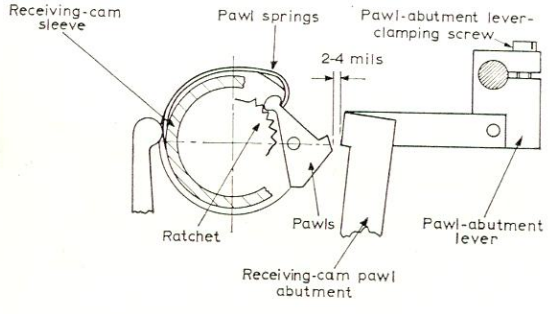


Fig 2.24. Receiving cam pawl abutment.

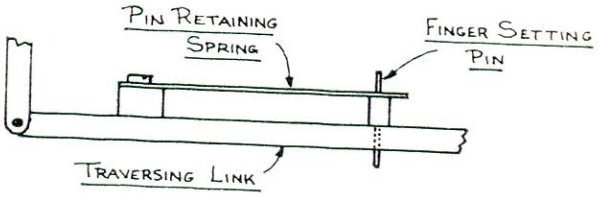


Fig 2.25. Finger setting pin.

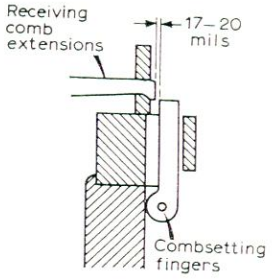


Fig 2.26. Fingers.

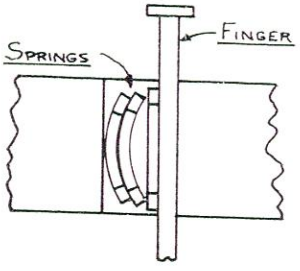


Fig 2.27. Finger springs, method of assembly.

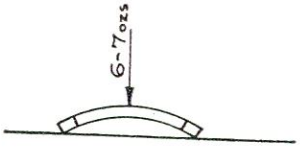


Fig 2.28. Finger springs, tension measurement.

With the position as above move the electromagnet armature to space (RHS) position. Slacken the pawl abutment clamping screw and adjust the lever on the trip bar to give a clearance of 2–4mil between the pawls and the pawl abutment. Tighten the clamping screw. See **Fig 2.24.**

The Finger-setting Pin

Rotate the motor by hand and ensure that the finger-setting pin is directly in line with each finger when the pin has been pushed fully in. To adjust—slacken the pin retaining spring fastening screw and move the pin retaining spring. Tighten the fastening screw. See **Fig 2.25.**

The Fingers

Remove the R.H. ribbon bracket in order to measure the force required to push each finger inwards. To adjust this force to 3–5oz remove the retaining plate from the finger block and remove the offending set of springs. Place each individual spring on a hard, flat surface and the force to depress the centre to touch the surface should be 6–10oz. Set the spring to obtain this, **Fig 2.28.** Re-assemble as shown in **Fig 2.27.** See also **Fig 2.26.** Remount the ribbon bracket.

Slacken the eccentric pin clamping screw on the comb-setting lever, with the fingers in the lowered position, adjust the eccentric pin so that when the fingers are pushed inwards and lifted the slots in the periphery of the combs be exactly centrally under the bellcranks for the code selected. Tighten the clamping screw. When in proper adjustment, with all of the fingers raised there should be a clearance between the comb extensions and the comb stop plate. See **Fig 2.29.**

Manually turn the motor until the fingers have just reset. Adjust the horizontal clearance between the comb extensions and the fingers to 17–20mil by slackening the finger-resetting trip bellcrank adjusting screw clamping screw, and adjusting the resetting trip bellcrank adjusting screw. Tighten the clamping screw. See **Fig 2.30.**

The Bellcrank Lifting Collar

Select letter "N" (SSMMS) as being convenient, by hand. Adjust the clearance between the bellcrank lifting collar and the fallen bellcrank to 6–8mil by slackening the eccentric coupling screw clamping screw, and adjusting the eccentric coupling screw. Tighten the clamping screw. The force to lift each bellcrank should be $1\frac{1}{2}$–$1\frac{3}{4}$oz measured at the type head end of the bellcrank. See **Fig 2.31.**

The Ribbon Mechanisms

Slacken the feed pawl pivot clamping screw on the comb-setting lever and adjust the feed pawl pivot so that each character feeds the ratchet wheel more than one whole tooth, about $1\frac{1}{4}$ teeth being optimum. Also check that the ratchet retention pawl is preventing excess reverse turning. Tighten the clamping screw. See **Fig 2.29.**

Manually turn the motor until the ribbon and jumper are at their highest position. Slacken the lock nut on the jumper abutting screw, adjust the screw until the top of the ribbon is level with the top of the type bars when a type bar touches the ribbon. (Unless the large fractional type bars are used, when the ribbon must be $\frac{1}{32}$in higher.) Tighten the locknut. See **Fig 2.32.**

Typehead and Clutch Latch

Slacken the bearing screw clamping screw and adjust the bearing screw to give an end play of the typehead, measured

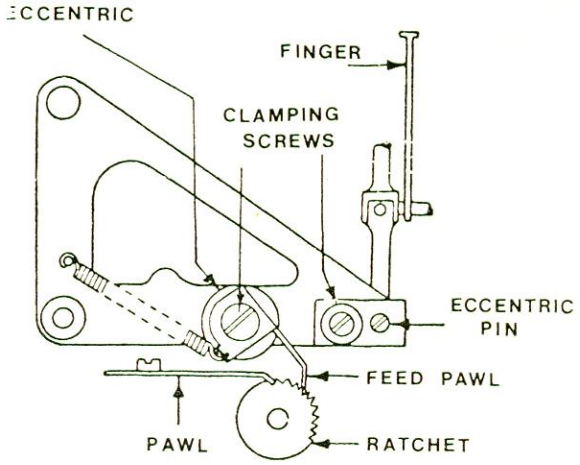


Fig 2.29. Comb-setting lever.

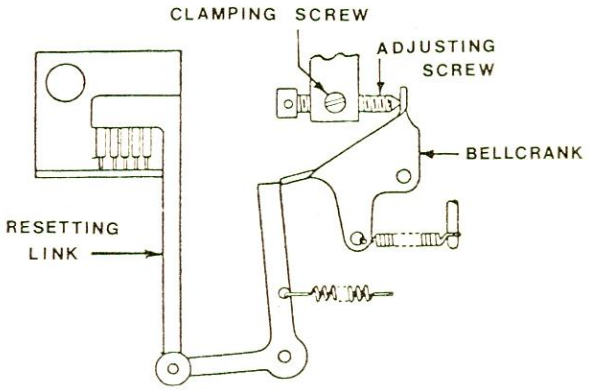


Fig 2.30. Finger-setting trip bellcrank adjustment.

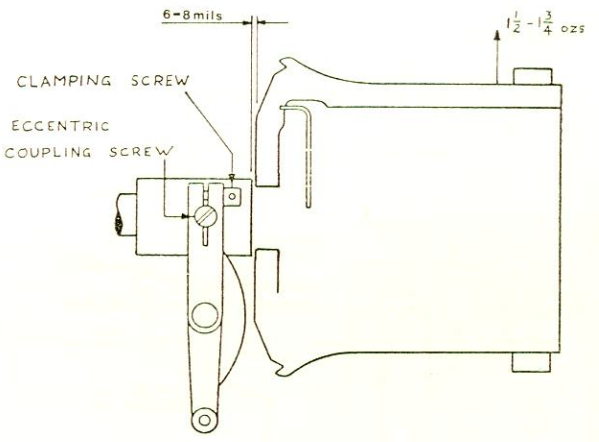


Fig 2.31. Bellcrank lifting collar adjustment.

at the engagement pins of 5–10mil. Tighten clamping screw. See **Figs 2.33** and **2.34**.

To give clearance of 30–35mil between the cam spring and the bellcranks, with the clutch unlatched, insert washers between the clutch drum and the combination head body. See **Fig 2.35**.

To give a clearance of 8–14mil with the clutch unlatched between the latch and the bellcranks, set the cam spring. See **Fig 2.35**.

Set the latch spring to give a force of 2–3oz with the clutch unlatched, to push the latch spring away from the cam spring, measured at the latch.

With the motor running at correct speed and the clutch unlatched, the tangential force, measured at the typehead periphery, necessary to hold the typehead should not be less than 3½lb. The tangential force measured at the typehead periphery necessary to latch the clutch should be between 3 and 4½lb.

Typehead Hammer

Manually select the letter "N" (SSMMS) and latch the typehead clutch. Adjust the two locknuts on the type hammer link to obtain the clearance of 32mil between the hammer head and the type bar. See **Fig 2.36**.

Slacken the type hammer spring clamping screw and with the letter "N" still latched adjust the position of the type hammer spring to bring the type hammer head exactly central with the "N" type bar. Tighten the clamping screw. See **Fig 2.36**.

To adjust the type hammer shock absorber spring, remove the type hammer and type hammer link, screw up the type hammer link until the spring is fully compressed and then release one turn. Refit the type hammer assembly back in position.

To obtain the clearance of 19–30mil between the bottom of the type hammer head and the type rack, pack under the type hammer pivot with washers. See **Fig 2.37**.

Carriage Adjustments

It is easier to make the first few adjustments with the carriage assembly removed from the teleprinter.

Feed Pawls

With the carriage at the extreme R.H. end of its travel, slacken the feed pawl pivot clamping screw and adjust the

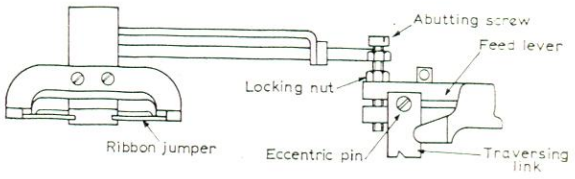


Fig 2.32. Ribbon jumper adjustment.

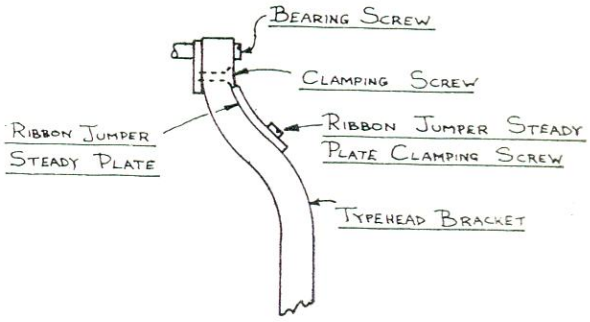


Fig 2.33. Typehead bracket.

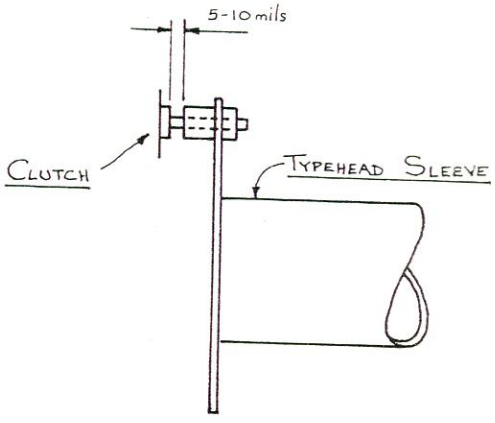


Fig 2.34. Typehead sleeve clearance.

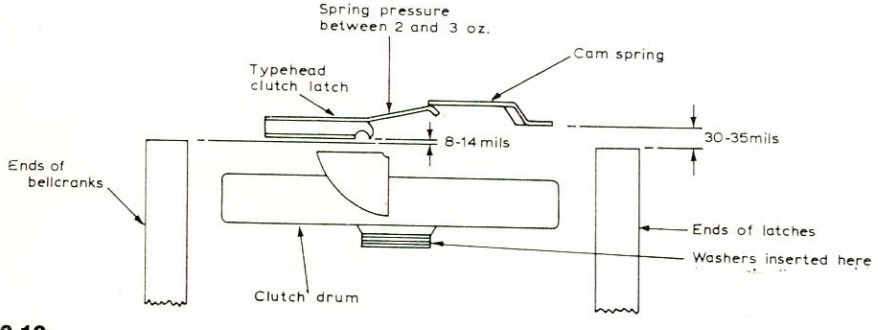


Fig 2.35. Clutch drum adjustment.

eccentric pivot to give 10mil clearance between the feed pawl and the next ratchet tooth. Tighten the clamping screw. See **Fig 2.38**.

Manually feed the carriage forward a few spaces (by operating the crosshead). With the retention pawl engaged in the ratchet and holding the carriage, slacken the retention pawl pivot clamping screw and adjust the eccentric pivot (both of these are at the rear of the casing) to give a clearance of 5–8mil between the feed pawl and the adjacent tooth on the ratchet. Tighten the clamping screw. See **Fig 2.39**.

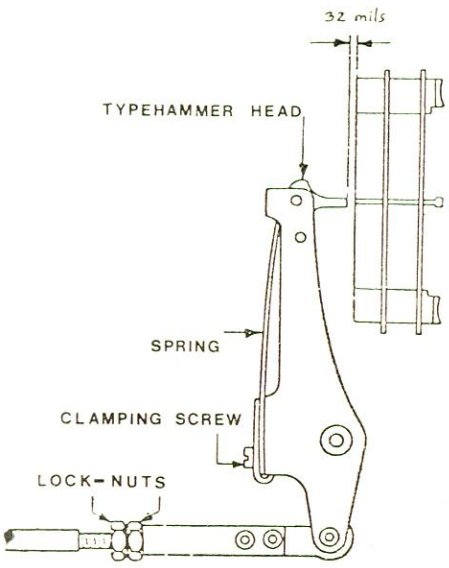


Fig 2.36. Typehammer.

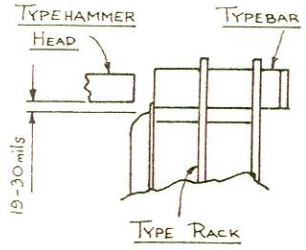


Fig 2.37. Typehammer, vertical adjustment.

Carriage Return and Line Feed Dogs

With the crosshead in its natural L.H. position, slacken the eccentric pin locking nut and adjust the eccentric pin (at rear of casting) to give a clearance of 10–15mil between the crosshead and the line feed and carriage return dogs. Tighten the locknut. See **Fig 2.40**.

With the carriage assembly back on the teleprinter, manually rotate the motor to bring the traversing link to its foremost position, ie with the finger-setting pin near No. 1 finger. Slacken the pivot locking screw on the feed lever and adjust the eccentric pivot to give a clearance of 15–25mil between the line feed or carriage return dog and the crosshead pawl. This is easiest measured from behind the carriage. Tighten the clamping screw. If this adjustment is altered radically then the ribbon jumper abutting screw may have to be readjusted as previously described. See **Figs 2.41** and **2.32**.

Set up:
Carriage return (SSSMS)
Line feed (SMSSS)
Bell (MMSMS)
Letter shift (MMMMM)
Fig shift (MMSMM)
in turn and check that the feed dog is thrown well clear of the

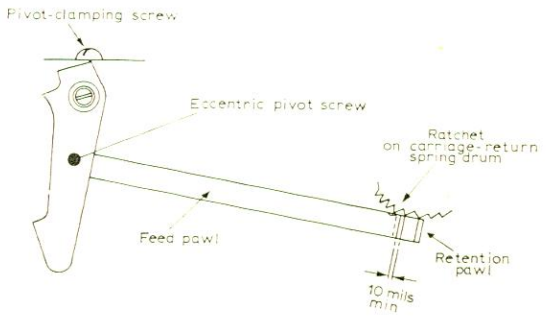


Fig 2.38. Letter feed pawl adjustment.

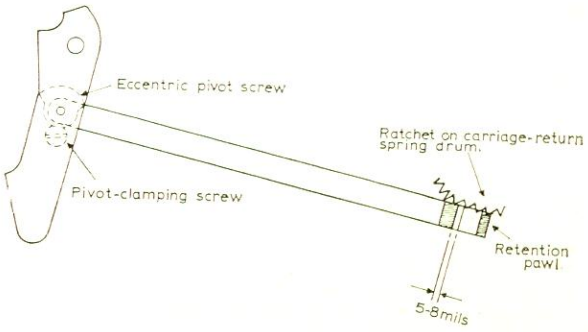


Fig 2.39. Retention pawl adjustment.

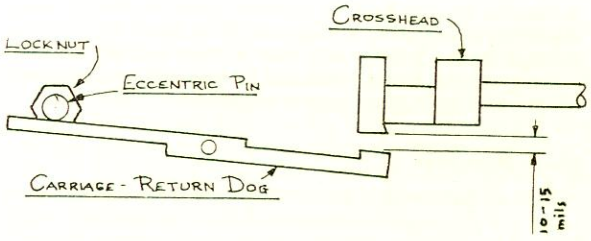


Fig 2.40. Line feed and carriage return dog adjustment.

crosshead. On the first two operations the appropriate dogs should engage fully with the crosshead.

Line Feed Mechanism

Slacken the jockey roller lever pivot locknut and adjust the pivot to place the jockey roller in the centre of its travel. Tighten locknut. Manually turn the motor and set up the line feed combination (SMSSS), with the line feed control set for double spacing, ie the line feed pawl nearest the ratchet. Turn the motor until the line feed pawl is at the bottom of its stroke. Slacken the feed pawl eccentric clamping screw and adjust the feed pawl eccentric until the jockey roller fully beds into the correct notch. Tighten the clamping screw. Set the line feed control for single spacing, again set up line feed and turn the motor until the line feed pawl is at the bottom of its travel. Slacken the lock nut on the line feed control and adjust the control eccentric relative to the spring disc until both single and double spacing are allowing the jockey roller to bed in its notches correctly. Tighten the lock nut. These adjustments sometimes need *slight* re-adjustment when the paper is inserted and the motor is run at full speed. See **Figs 2.42** and **2.43**.

Carriage Return Mechanism

Slacken the chariot rail clamping screws and adjust the rail so that the chariot will run freely without shake. Tighten the clamping screws. The spring on the chariot should lightly touch the chariot rail when the chariot is at the extreme R.H. end.

Move the carriage to the extreme L.H. end of its travel and depress the carriage return key. (At the rear L.H. end of the carriage.) The force required to hold the carriage in this L.H. position should be between $2\frac{1}{2}$–$3\frac{1}{4}$lb. With the piston about to enter the carriage cylinder the force required to hold the carriage should differ from the previous one by no more than $1\frac{1}{4}$lb.

To adjust the spring to obtain the required figures—remove the platen knob, jockey roller spring and the bell hammer assembly. Set the carriage halfway along its travel, remove the L.H. bearing bracket, move the platen spindle to the left and remove the carriage assembly. Hold the spring drum, release the two pawls and let the drum unwind slowly, counting the turns. If only a small adjustment is needed remove the screw holding the bearing spindle (at the rear of the casting) and withdraw the spring drum. Turn it through $\frac{1}{2}$ a turn and replace, refit the bearing spindle-screw. Now wind up the drum $\pm \frac{1}{2}$ turn as required. If however a larger adjustment is needed do not remove the drum but rewind to $\pm$ 1 turn as required. Manually operate the crosshead until the drum stops turning. Now replace the carriage at its extreme L.H. position. Refit the bell hammer assembly, jockey roller spring and platen knob. See that the carriage feeds correctly and that it does not hit the L.H. bearing bracket if the crosshead is operated continuously. Check the forces again, reset if necessary.

Shock Absorber

Slacken the carriage shock absorber valve plate clamping screw and adjust the valve plate until the carriage will return from any position without shock and without bounce. Tighten the clamping screw. The clamping screw is accessible

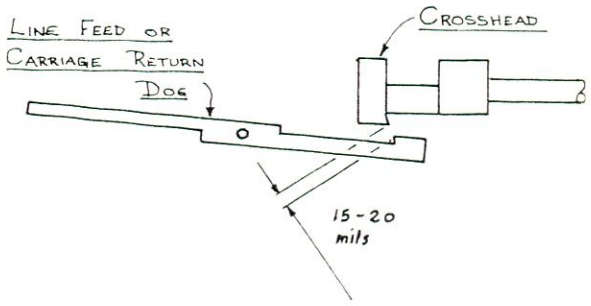


Fig 2.41. Clearance, line feed/carriage return dogs and cross head pawl.

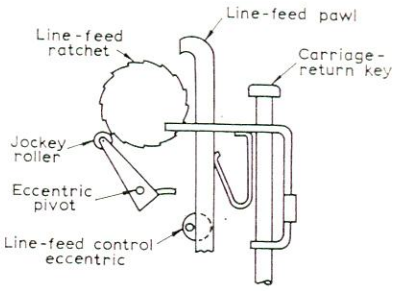


Fig 2.42. Line feed mechanism, side view.

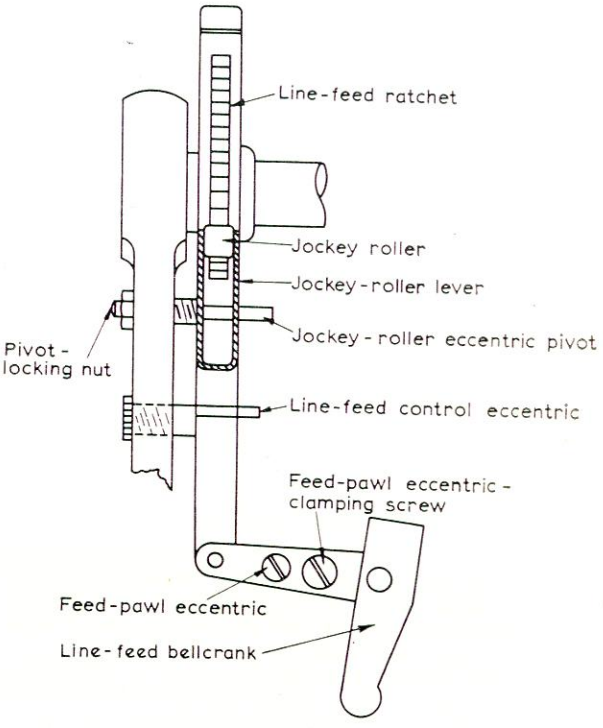


Fig 2.43. Line feed mechanism, end view.

through a hole in the R.H. end bearing bracket—some machines also have a hole in the platen knob—otherwise the knob must be removed.

Carriage Latch

Slacken the carriage stop eccentric sleeve locking screw and adjust the eccentric sleeve to obtain a clearance of $\frac{1}{8}$in between the typebars and the platen with the carriage held against the stop. Tighten the locking screw.

Slacken the latch stop eccentric sleeve locking screw and adjust the sleeve until the carriage locks securely and without play. Tighten the locking screw. See **Fig 2.44**.

Other Units: The Auto Start-stop Switch

With the electromagnet held in the mark position (L.H.) and the weight lifting pin fully engaged in one of the worm wheel holes, slacken the trip spindle clamping screw and adjust the spindle so that it just touches the end thrust spring (a leaf spring). Tighten the clamping screw. See **Fig 2.45**.

With the pin still fully engaged in the worm wheel hole, slacken the starter boss clamping screw and adjust the starter boss to obtain a clearance of 5–10mil between the starter boss and the starter trip lever extension, with the electromagnet armature still at the mark position. Tighten the clamping screw on to the flat on the spindle. See **Fig 2.45**.

To obtain a clearance equal to the diameter of one hole between the weight-lifting pin and the shroud, with the weight in the down position, release the locking screws on the weight and locating collar, move the weight as required and lock the locking screws with the locating collar just touching the weight. See that the starter trip lever extension moves freely into the slot in the starter boss. See **Figs 2.46** and **2.47**.

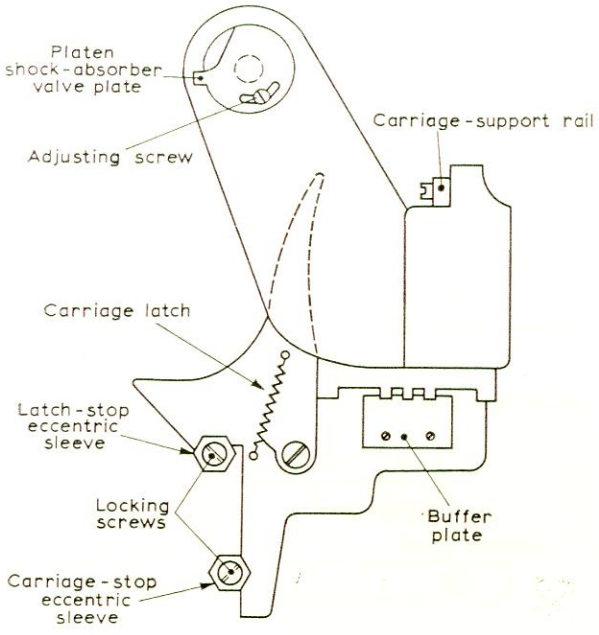


Fig 2.44. Carriage latch.

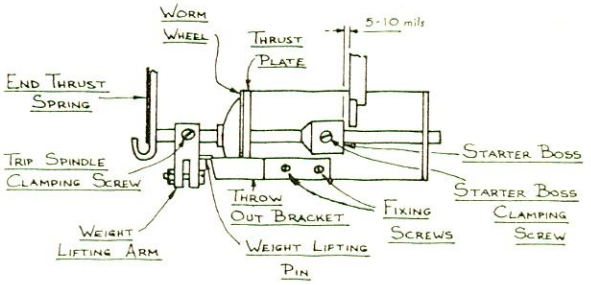


Fig 2.45. Starter switch trip mechanism.

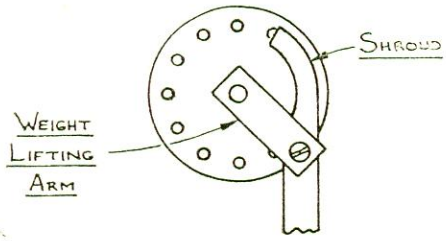


Fig 2.46. Starter switch weight lifting arm.

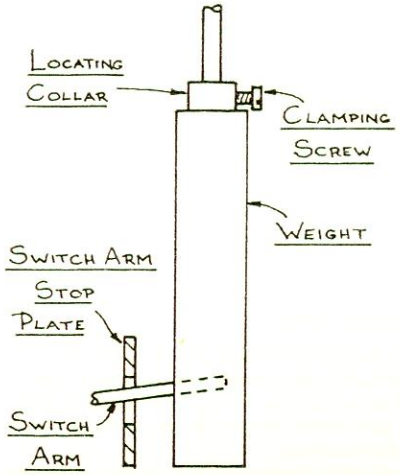


Fig 2.47. Starter switch weight assembly.

With the weight lifted and the weight-lifting pin fully engaged in the hole exposed at the top of the shroud the force required on the end of the trip spindle to disengage the weight lifting pin from the worm wheel should be less than 3oz. With the end thrust spring removed this should drop to $\frac{3}{4}$oz. If the values are not these, check that everything is free to move, then set the end thrust spring. With the weight in the down position the force required should be less than 1oz with the end thrust spring in place.

Remove the switch cover and bend the switch arm so that when the motor is running and the electromagnet armature

is in the mark (L.H.) position, the motor is stopped with the weight-lifting pin coming to rest ½ a hole diameter from the shroud top.

Let the auto start-stop switch switch off the motor. Slacken the throw-out bracket fixing screws and adjust the throw-out bracket to obtain a clearance of 15–20mil between the throw-out bracket and the weight-lifting arm screw. Tighten the fixing screws. With the switch contacts shorted out the throw-out bracket should release the weight before the switch arm hits the switch arm stop plate. See **Fig 2.47.**

Answer Back Unit

With the unit in the rest position slacken the answer back unit fixing screws and adjust the position of the answer back unit to give a clearance of 10–20mil between the ends of the combination bars and the edge of any answer back ward. It may be necessary slightly to adjust the abutment screws in the answer back unit. Tighten the fixing screws.

Manually turn the motor and release the answer back detent, stop turning the motor when the third ward is just below the top of the combination bars. Slacken the trip cam fixing screws and alter the trip cam relative to the drum so that the trip lever is fully bedded in the third notch, with the ward still in the same position. Tighten the fixing screws. With this adjustment correct—switch on the motor, lift the answer back detent and the drum should revolve without binding. See **Fig 2.48.**

Select WRU on the teleprinter receiver (MSSMS) manually. When the answer back detent has been operated, slacken the release shaft lever adjusting screw locking nut and adjust the adjusting screw to give a clearance of at least 10mil between the answer back detent and the face of the answer back drum. Tighten the locking nut. See **Figs 2.49** and **2.50.**

Slacken the guide bracket clamping screw and adjust the position of the guide bracket to give a clearance of 5mil between the keybar extension and the cutaway portion of the detent link, with the WRU key depressed. Tighten the clamping screws. It may be necessary to set the keybar extension to obtain free movement. See **Fig 2.50.**

To Change the Code

Remove the answer back cover. Loosen the ward clamping plate locknut, which is on the electromagnet side of the ward drum; use a tommy bar to hold the spindle. Turn the ward clamping plate until the slot is opposite the required ward and slide the ward out.

To cut a ward remember that a slot represents a mark element. The individual slots should be $\frac{1}{10}$in wide and $\frac{3}{32}$in deep.

It is advisable to start the code with carriage return, line feed and letters, unless some special code is envisaged.

When the wards have been replaced in their correct positions, turn the ward clamping plate so that the slot does not line up with a ward and tighten the locknut. See **Fig 2.51.**

Motor Governor: Series Governor

Slacken the contact clamping screw and adjust the contact to obtain an armature movement of 15–20mil measured at the contact. Tighten the clamping screw.

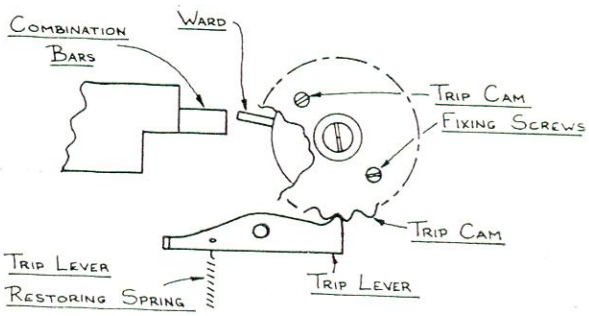


Fig 2.48. Answer-back, trip cam.

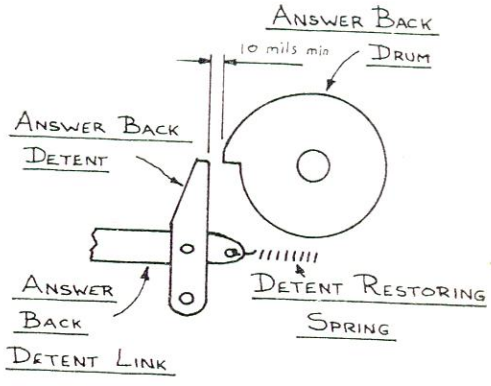


Fig 2.49. Answer-back trip, shaft.

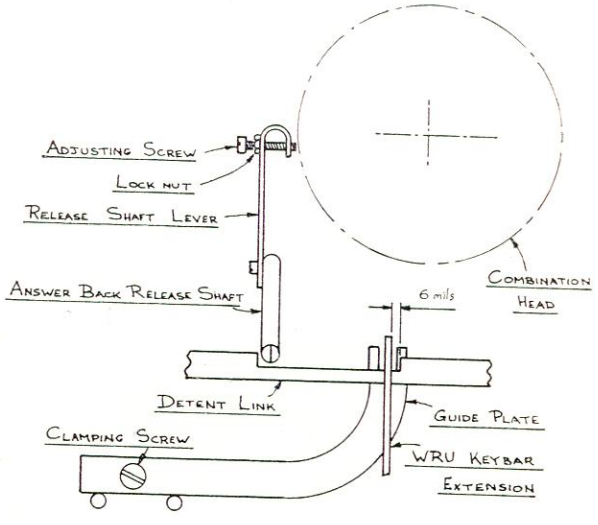


Fig 2.50. Answer-back release.

Shunt Governor

Slacken the contact clamping screw and adjust the contact to give a clearance of 20–25mil between the two contacts. Tighten the clamping screws.

Differences Between New and Old Machines

The modern Creed type 7 teleprinters are basically the same machine as the older type 7B. However, there are some differences, the most noticeable being: the modern machines have an orientation device, or range finder; they have a modified carriage shock absorber; the electromagnet assembly is slightly different; the clutch and typehead assembly is re-designed; the motor is slightly different, and there are several different types of keyboard that can be fitted. Also the modern machines can be fitted with a reperforator attachment.

In the main the adjustments follow the same pattern as already indicated; however, included below are the adjustments which are radically different.

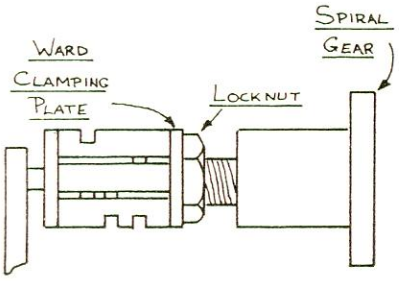


Fig 2.51. Answer-back drum.

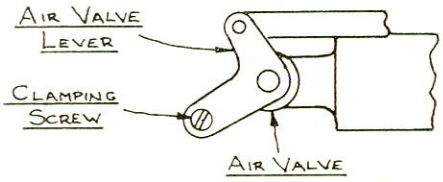


Fig 2.52. Air valve adjustment.

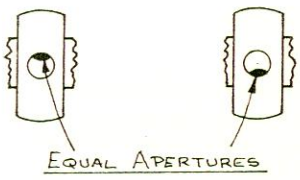


Fig 2.53. Air valve adjustment.

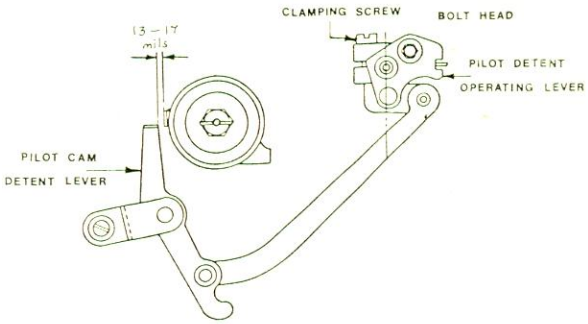


Fig 2.54. Pilot cam detent.

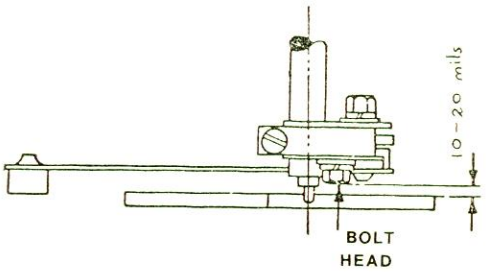


Fig 2.55. Pilot cam detent.

The Carriage Shock Absorber

Slacken the air valve lever clamping screw and adjust the position of the air valve lever relative to the air valve, to obtain equal apertures in the air valve at the extremes of the carriage travel. Tighten the clamping screw. See **Figs 2.52** and **2.53**.

Pilot Cam Detent

Slacken the pilot cam detent operating lever clamping screw and adjust the position of the pilot cam detent operating lever so that there is a clearance of 10–20mil between the plate and the bolt head and also, with the electromagnet armature held against the space (R.H.) stop, there is a clearance of 13–17mil between the pilot cam detent lever and the pilot cam lug. Tighten the clamping screw. See **Figs 2.54** and **2.55.**

Receiving Cam Abutment

To check the receiving cam abutment a special tool is normally used. This comprises a double ended plug gauge, one end being 47mil diameter, the other 53mil diameter. However, for the adjustment two drills of appropriate size could be used—a $\frac{3}{64}$in diameter drill for the 47mil diameter size and a No. 55 for the 53mil diameter size.

Slacken the abutment lever clamping screw and adjust at the screwdriver adjustment point, so that the relative positions of the abutment and the sickle lever fulfil the following conditions.

With the orientation device set at 50, manually turn the motor until the receiving cam is arrested by the abutment, withdraw the abutment, allowing the pawls to drop into their ratchet. Return the abutment so that it touches the pawls. The 47mil diameter gauge should pass between the retaining ring lug and the sickel lever without moving the sickle lever. However, the 53mil diameter gauge should move the sickle lever when tried in the same position. Tighten the clamping screw. See **Figs 2.56** and **2.57**.

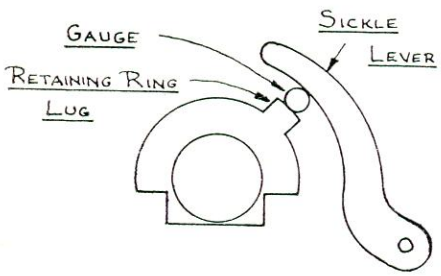


Fig 2.56. Receiving cam detent.

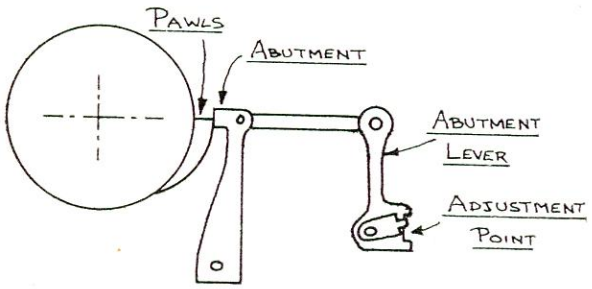


Fig 2.57. Receiving cam detent.

LUBRICATION INSTRUCTIONS

Creed Model 7

After Each 300 Hours of Operation

No. 1 Lubricant

1. Clean the platen spindle and running bar with a cloth dipped in paraffin oil. Apply a few drops of lubricant to the platen spindle and the running bar.
2. Apply a small quantity to the following parts:
   (*a*) Starter trip spindle
   (*b*) Starter trip lever pivot
   (*c*) Ribbon feed change rods (excessive lubrication may cause sticking).

No. 2 Lubricant

1. Fill all oil cups and oil holes, paying special attention to the following:
   (*a*) Finger setting block (oil sump)
   (*b*) Cam sleeve oil hole (cam unit)
2. Saturate all lubricating felts, paying special attention to the following:
   (*a*) Oil cover over the cam levers
   (*b*) Typehead lubricator felt
   (*c*) Typehammer pivot felt
3. Lubricate all pivots, friction faces and couplings, paying special attention to the following:
   (*a*) Cam ratchet and pawls (cam unit)
   (*b*) Cam tracks (cam unit)
   (*c*) Finger setting pin (cam unit)
   (*d*) Pilot cam clutch (cam unit)
   (*e*) Orientation link spring (cam unit)
   (*f*) Bellcrank lifting collar engagement face (combination head)
   (*g*) Typehead clutch lining (*N.B.* Avoid surplus oil (typehead unit).)
   (*h*) Clutch band engagement with typehead driving spring (typehead unit)
   (*i*) Latch pivot (typehead unit)
   (*j*) Steel worm gears (starter switch control unit)
   (*k*) Overthrow stop engagement face
   (*l*) Ribbon driving shaft, ratchet and crown wheel
   (*m*) Ribbon jumper grooves in typehead support bracket
   (*n*) Link guide block (page attachment unit)
   (*o*) Spring drum ratchet wheel (page attachment unit)
   (*p*) Platen spindle ratchet (page attachment unit)
   (*q*) Platen end bearings (page attachment unit)
   (*r*) Felt washers on the lock bar and air valve connector (page attachment unit)
   (*s*) Pivots of the rollers at the top and bottom of the dashpot lever (page attachment unit)
   (*t*) Control lever bearing bushes and the pivots of the feed throw-out lever (control unit)

   N.B. An excess of oil is liable to cause some sluggishness in the operation of the carriage.

No. 4 Lubricant

1. Apply a little grease to the following parts:
   (*a*) Trip shaft cone pivots (cam unit)
   (*b*) Hammer head spring engagement and shock-absorber spring (typehammer unit)
   (*c*) Working faces of the ears on the stop plates (typehead unit)
   (*d*) Working faces between spring anchors and retaining plate (typehead unit)
   (*e*) Working edges of the control levers and the feed throwout lever (control unit)
   (*f*) Carriage rack and spring drum gear wheel (page attachment unit)

No. 5 Lubricant

1. Apply a little grease to the following parts:
   (*a*) Striker blade guides on the cam unit
   (*b*) Mainshaft, cam unit and typehead gears, and the fibre starter worm
   (*c*) Jockey bush on the ribbon driving shaft
   (*d*) Outsides of the rollers on the dashpot lever

After Each 3,600 Hours of Operation

Dismantle and clean the machine. Lubricate all points as above, with the following additions:

No. 2 Lubricant

1. Soak the following parts for 2–3 hours in the lubricant:
   (*a*) Typehead clutch friction washers (typehead unit)
   (*b*) Latch arm (typehead unit)
   (*c*) Stop arm (typehead unit)
   (*d*) Clutch body (typehead unit)
   (*e*) Typehead support bracket (control unit)
   (*f*) Cam release lever bracket (cam unit)
   (*g*) Pilot cam friction washers (cam unit)
2. Lubricate the following parts:
   (*a*) Receiving comb bearings and spring pivots (combination head)
   (*b*) Shift comb lever pivot and jockey spring (combination head)
   (*c*) Counter gear bearing pin (if a period of operation counter is fitted)
3. Apply a trace of oil to the ribbon guide pins on the ribbon feed brackets, taking care that none reaches the outside of the rollers.
4. Soak the bellcrank bearing oiling wick in the lubricant for a few minutes.
5. Apply a few drops of the lubricant to the following parts:
   (*a*) All oilite bearings (page attachment unit)
   (*b*) Leather piston washer (page attachment unit)
   (*c*) Oiling pads in the pressure roller release lever bearing blocks (page attachment unit)

No. 4 Lubricant

1. Repack the following ball bearings:
   (*a*) Combination head (2)
   (*b*) Main shaft (2)
   (*c*) Motor (2)
2. Apply a light smear of grease to the ground faces of the armature extension and of the gap in the armature stop plate.

No. 5 Lubricant

1. Smear a little of the lubricant on the following parts:
   (*a*) Periphery of bellcrank bearing (combination head)
   (*b*) Both ends of the bellcranks (combination head)
   (*c*) Magnet armature pivots after cleaning
   (*d*) Adjusting block friction spring (cam unit)
   (*e*) Counter driving gear and counter driving worm (if a period of operation counter is fitted)
   (*f*) Counter driving pin on the counter driving gear (if a period of operation counter is fitted)

Lubricants

The following lubricants are recommended:

No. 1 Lubricant—thin oil, such as:
Clavus Oil 17 (Shell Oil J.Y.1)

No. 2 Lubricant—medium oil, such as:
Talpa Oil 30 (Shell Oil C.Y.2)

No. 4 Lubricant—grease, such as:
Shell Nerita Grease 3 (Shell VW)

No. 5 Lubricant—grease, such as:
Mobilgrease No. 2.

TABLE OF RECEIVER FAULTS—Creed Model 7

All receiver faults, whether they are of the obvious kind that do not require systematic localization or are of the less obvious kind that do, produce specific fault symptoms on some part of the receiver.

The main kinds of fault symptoms with their possible causes are listed in the following table. This table is not meant to be exhaustive, or to convey the idea that all the faults listed are likely to occur on any given machine.

	Fault	Possible Causes
		SELECTING MECHANISM
A	Frequent failures on selecting fingers	1. Spacing bias on electromagnet 2. Finger-setting blade too low 3. Spacing reaction on armature 4. Finger-setting blade too far from pin 5. Finger resetting adjustment wrong 6. See Fault Section C
B	Frequent extras	1. Marking bias on electromagnet 2. Finger-setting blade too high 3. See also Fault Section C
C	Occasional extras and/or failures	1. Bias on electromagnet 2. Magnet strength incorrect 3. Receiving cam sleeve loose 4. Receiving pawls sluggish, pawl springs faulty 5. Finger-setting blade vertical adjustment faulty 6. Detent adjustment faulty 7. Reaction on armature faulty 8. Finger-setting blade horizontal adjustment faulty 9. Finger-setting blade worn or bent 10. Finger springs with wrong tension 11. Cam sleeve driving ratchet teeth broken 12. Slackness of trip shaft bearings 13. Cam rollers worn
D	First finger failing	1. Finger resetting adjustment wrong 2. Finger spring tension incorrect
E	Fifth finger giving extras	1. Receiving cam sleeve loose 2. Finger adjustments incorrect 3. Fingers badly aligned
		TRANSLATING MECHANISM
F	Correct bellcrank not dropping	1. Finger lift adjustment not correct 2. Bellcrank lift adjustment incorrect 3. Combs sticky
G	Typehead spinning	1. Bellcrank lift adjustment incorrect 2. Bellcrank lifting collar worn 3. Cam roller or cam track worn
H	Shift not properly working	1. Shift lever spring binding on anchor pins 2. Shift lever binding on pivot 3. Springs on shift bellcrank weak 4. Shift lever spring too strong
		PRINTING MECHANISM
I	Bad impression	1. Typehammer adjustments incorrect 2. Ink ribbon needs changing 3. Height of ink ribbon jumper incorrect 4. Ribbon feed or feed change mechanism faulty 5. Distance between typehead and platen wrong
J	Typehead clutch not latching	1. Worn clutch lining 2. Worn clutch band
		FUNCTION FAULTS (PAGE ATTACHMENT UNIT)
K	Carriage not returning	1. Crosshead adjustment incorrect 2. Dog spring too strong 3. Dog loose on pivot 4. Engaging tooth of dog worn
L	Carriage partially returning	1. Carriage return trip bellcrank spring weak 2. Trip bellcrank damaged or worn
M	Carriage returning with too much force	1. Air valve adjustment faulty
N	Line feed failing	1. Crosshead adjustment incorrect 2. Dog spring too strong 3. Dog loose on pivot 4. Engaging tooth of dog worn 5. Line feed pawl worn
O	Irregular line feed	1. Line feed adjustments incorrect 2. Line feed pawl worn

TABLE OF RECEIVER FAULTS—Continued

Fault	Possible Causes
P Letter feed failing	1. Carriage feed pawl adjustment incorrect 2. Carriage retaining pawl adjustment incorrect 3. Crosshead adjustment incorrect 4. Carriage feed pawl tooth worn 5. Spring drum teeth worn 6. Letter feed dog engagement tooth worn 7. Carriage return trip bellcrank preventing feed
Q Non-feed function failing	1. Crosshead adjustment incorrect 2. Buffer spring adjustment incorrect
R Overprinting	1. Air valve adjustment incorrect
S Motor not starting	MOTOR, GOVERNOR AND STARTER SWITCH UNITS 1. Motor or governor brushes need renewing 2. Commutator requires cleaning 3. Starter switch unit adjustment incorrect
T Motor not stopping	1. Starter switch unit adjustment incorrect
U Motor overheating	1. Brush rocker adjustment incorrect 2. Excessive load from teleprinter (check bearings)
V Governor not governing	1. Contacts require adjusting or changing 2. Governor brush broken 3. Carbon dust between governor brush connections 4. Carbon dust between slip rings
W Excessive sparking	1. Grooves in the commutator 2. Brush springs weak 3. Brushes worn 4. Disconnection in armature windings 5. Brush rocker adjustment incorrect
X Excessive brush wear	1. Carbon dust between commutator segments 2. Mica needs undercutting 3. Worn commutator

TELEPRINTER No. 7B STANDARD ADJUSTMENTS

Adjustment	Pressure or Gauging	Remarks
TRANSMITTER STRIKER TYPE		
Striker timing lever	10–20mil	Striker in highest position
Striker stop plate	15mil	Gauge between heels of third and fourth selecting levers and contact operating lever
Transmitter contact gap	6mil	Striker lever to fall equal distances on either side of tongue
Jockey roller pressure and tongue neutrality	4–5oz	Neutral
Striker timing lever spring	4½–5½oz	Measured at left-hand side of striker. Spring on right-hand side of its anchor
Selecting lever springs	4½–6oz	Measured at right-hand end
SEND-RECEIVE SWITCH		
(*a*) Lever and buffer	4–6mil	*Motor running*: buffer tight in lever
(*b*) Contact gap	6mil	
Contact operating lever spring	5–8oz	All selecting levers spacing
Pawl abutment lift	3–20mil	Check on several keys
Resetting lever	6–20mil	*Motor running*
Keybars	6–8½oz	*Motor running*: not more than 1½oz difference between all keys
TRIP BAR BACK STOP		
Locking bar No. 2	5–6mil	
Comb bars and springs	3½–4½oz	Free in guide plates
Locking bar No. 1	4–5oz	Free in guide plates
RECEIVER		
Fitting abutments		Abutments must be in contact
Receiver-cam sleeve	1·5mil max	Free, minimum end play
Cam unit clutch mechanism	1oz	To disengage the pawl abutment from the pawls. *Motor running*
Pawl abutment (tension)	2½–3½oz	
Electromagnet armature travel	22–25 mil	Electromagnet No. 1
Electromagnet armature travel	28–32 mil	Electromagnet No. 2
Field unit spring	3lb min	Gauge on heel of field unit
Electromagnet neutrality No. 1	8–12oz 9–11 Unit No. 2	Electromagnet link disconnected below centre of pin
Adjustment of tripshaft and blade	5 mil approx	
Finger-setting blade (horizontal)	80mil	To include backlash of blade
Pawl abutment	2mil max	
Electromagnet neutrality No. 2	—2oz	Reduction should not be more than 2oz
Finger-setting blade reaction	—2½ Unit No. 2	
Finger-setting pin	—	Central with finger, when finger is half-set
Finger-lift	—	Comb plates should be level
Finger resetting	17–20mil	Released during start signal
Finger pressure springs	6–10oz	Measured on flat surface
Finger pressure	3–5oz	
Bellcrank lifting lever		Use "N" bellcrank
CONTROL LEVER-UNIT		
Shoe on control lever	central	Bellcrank central on shoe
Control levers	18–44mil	Between front body plate and control lever tips
TYPEHEAD UNIT		
Types	3–4oz	To just move type retaining plate
Typehead end play	5–10mil	Measure in tightest position
Typehead latch cam	30–55mil	Unlatched + or — shims
Typehead clutch latch	8–14mil	Typehead unlatched
Typehead latch spring	2–3oz	Clutch unlatched
Clutch latch	13–20mil	Use "N" bellcrank
Clutch torque A	3½lb min	To rotate the typehead backwards
Clutch torque B	3–4½lb	To latch on selected bellcrank
Printing hammer head	central	Rear end of type central with hammer head
Printing hammer shackle spring	1 turn	Release spring one complete turn
Printing hammer head	$\frac{1}{32}$in	Between typehammer and type face. Use "N" type
Ribbon feed ratchet	1⅓ teeth	
Ribbon jumper	—	Jumper free in guide
Ribbon jumper steady plate	2mil approx	Between each arm of steady plate
Ribbon lift	$\frac{1}{32}$in	Top of ribbon above type
Ribbon jumper clearance	functional	Clear of typehead
Ribbon feed spindle jockey spring	12–16oz	At ends of spindle
AUTOMATIC START STOP SWITCH		
Starter boss	6–10mil	Check that switch will operate on the incoming signal
Spindle pressure	¾–2¾ oz	
Throwout bracket	functional	
Position of boss (switch on)	functional	
ANSWER BACK UNIT		
Ward clearance	10–20mil	Adjust fitting abutment on keyboard
Trip cam	functional	Ward to engage top of combination bars
Release shaft	10mil	Detent held to the right
Trip mechanism "D" extension	6mil	
CARRIAGE		
Chariot rail	functional	
Carriage friction	1¾lb	Not more than 1¾lb
Carriage return spring	2½–3¼lb	End to end variation 1¼lb
Characters per line	69chtrs	Check by operation of crosshead
Letter feed pawl	10mil min	Carriage at extreme right

Adjustment	Pressure or Gauging	Remarks
Retention pawl	5–8mil	Carriage fed a few spaces to left
Carriage unit dashpot	functional	For satisfactory damping
Carriage latch	$\frac{1}{8}$in	Between type face and platen
Clutch crosshead	10–25mil	Vertical measurement
Letter-feed dog	6–10mil	Between feed throw-out lever and plate
Carriage-return and line dogs	10–15mil	Horizontal measurement
LINE-FEED MECHANISM		
Line feed pawl	0–10mil	Pawl in maximum forward position
Line feed pawl movement	functional	Check on double line spacing
Jockey roller	functional	Jockey roller fully-bedded
Line feed pawl buffer	functional	Buffer lightly touching pawl

Adjustment	Pressure or Gauging	Remarks
Pressure rollers	functional	
Chariot buffer spring	functional	Should just touch rail. Check that chariot is central
End of line bell	55 times	Operate crosshead 55 times
Pawl throw-out lever	1–5mil	Observe clearance
Spring tensions	functional	
Functional tests		
MOTOR		
Governor contacts	20–25mil	Use governor contact clamp
Governor brush springs	5 ± $\frac{1}{2}$oz	Reduces to 3oz for worn brushes
Measurement of motor speed	3,000rpm	
Motor maintenance		
Teleprinter lubrication		Tables 1 and 2

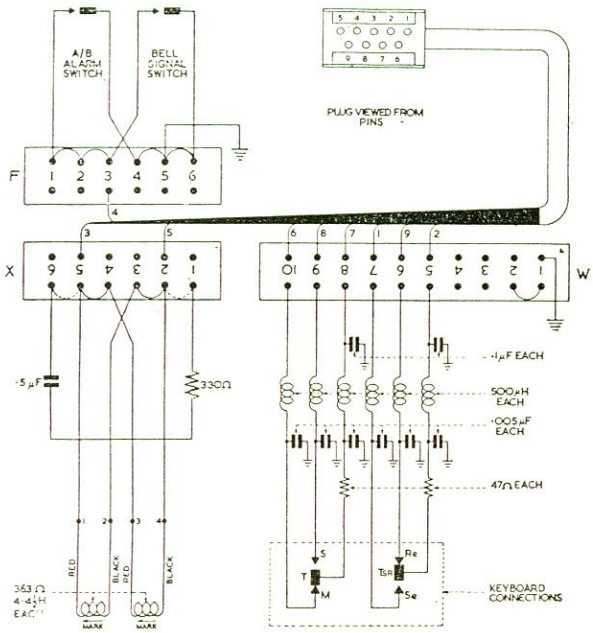


Fig 2.58a. Model 7, nine-pin plug wiring.

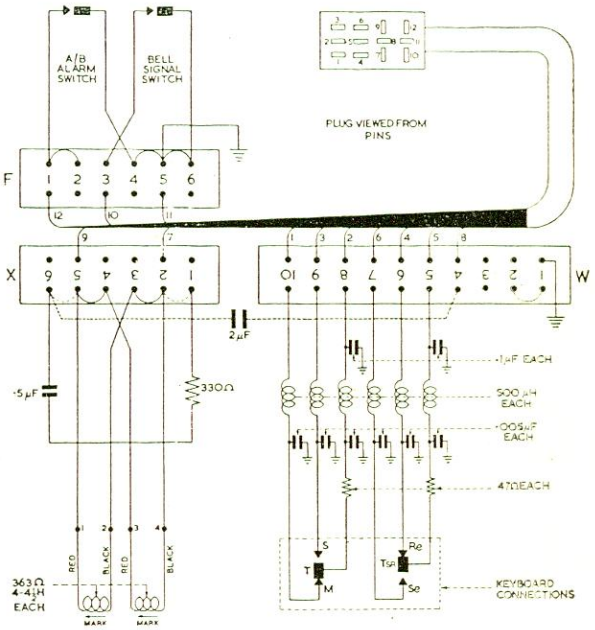
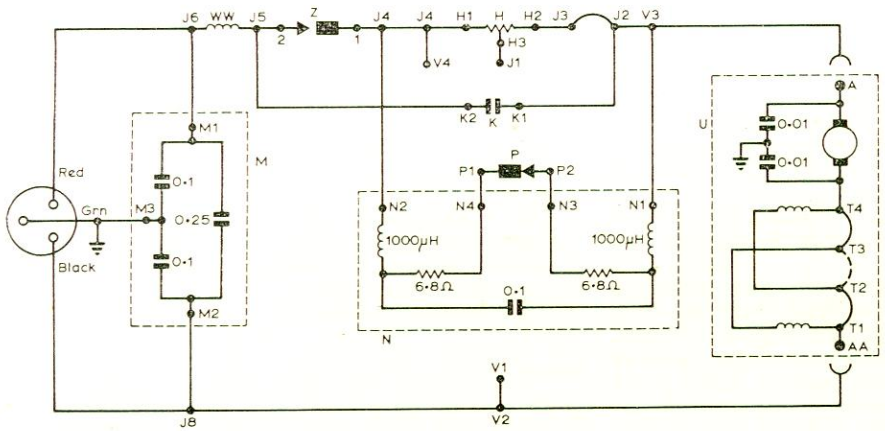


Fig 2.58b. Model 7, twelve-pin plug wiring.



A — Motor plug pin
AA — Motor plug pin
H — Governing resistor 500 + 500Ω
J — Terminal block
K — Capacitor 0·5μF
M — RIS Capacitor 0·1 – 0·1 – 0·25μF
N — Governor RIS unit
P — Governor brush block
T — Motor field strapping block
U — AC-DC series motor
V — Motor connection block
WW — Inductor 1000μH
Z — Starter switch

Fig 2.59. Model 7, motor wiring.

THE CREED MODEL 75 TELEPRINTER

The Creed 75 Teleprinter is a compact machine, designed for operation at 45, 50 or 75 bauds, and is available also as a dual-speed unit, permitting manual speed change by the operator between 45 and 50 bauds.

The signalling mode may be single or double current. When operating on single current the line current should be 50mA at 120V, and on double current, +80, 0V–80V, 20–25mA.

OUTLINE OF OPERATION

Reception

Signals from the distant teleprinter are received on a polarized electromagnet whose armature moves between the marking and spacing stops in response to the reversals of line current (double-current working), or the current and no-current elements (single-current working), which compose the incoming code combination.

The start signal releases the selector unit camshaft which then makes one revolution during which it converts the movements of the electromagnet armature into a static setting on five two-state selecting pins in the translator unit. Towards the end of this revolution the selector unit releases the translator shaft and is brought to rest immediately afterwards by the stop signal.

While the next character is being processed by the selector unit and transferred on to a second group of five pins, the translator unit, acting through the aggregate motion mechanism, positions the typehead in accordance with the code established on the first group of pins. The typehead then impresses the selected character on the paper and afterwards comes to rest until released at the end of the next selection cycle.

Transmission

Operation of the keyboard sets up the code combination of the selected key on five combination bars and simultaneously depresses a trip bar common to all keys. Each combination bar is mechanically linked to one of the five code selecting pins in the translator unit; the trip bar is linked to the translator clutch release mechanism. The single act of depressing a key will thus create the appropriate code combination, convey this code to the translator unit, and then release the translator unit clutch.

The transmitter unit is located above the translator unit and consists of two banks of contacts which are mechanically independent but electrically interconnected as shown in **Fig 2.60**. One bank is made up of five changeover contact sets which reflect the code setting on the selecting pins and which operate simultaneously. The other bank consists of seven make contact sets which operate sequentially; five of these are linked to their associated changeover code contacts and the remaining two contacts produce the start and stop signals.

Once the code for the depressed key has been established on the selecting pins and the translator clutch has been released, the changeover contact bank takes up the code setting. The seven sequential contacts, which are driven by cams on the translator shaft, then scan this setting at the appropriate intervals and so transmit the required sequence of start signal, five variable code elements, and the stop signal to line.

The Model 75 teleprinter with tape reader and reperforator attachment (courtesy ITT-Creed Ltd).

TECHNICAL DESCRIPTION

Construction

The machine is of unit construction and consists of 16 units listed below:

1. Main Base Unit
2. Motor Unit
3. Electromagnet
4. Selector Unit (includes most of the operating mechanism of the Automatic Motor Switch, although the actual motor switch is located underneath the main base)
5. Translator Unit
6. Typehead Unit
7. Aggregate Motion Unit (links Translator Unit to Typehead Unit)
8. Ribbon Unit (carried on typehead carriage casting)
9. Platen Unit (carries paper roll and paper transport mechanism)
10. Transmitter
11. Keyboard
12. Selector Frames Unit (links Keyboard to Translator Unit and Transmitter)
13. End-of-Line Indicator and Carriage Return Spring Drum
14. Reperforating Attachment (with machines fitted with a Reperforating Attachment, a dummy plinth which stores the reel of paper tape is located underneath the main base)
15. Answer-Back Unit
16. Operation Counter

Drive

The receiver has two camshafts—a selector shaft and a translator shaft. Both are linked through friction clutches to the main drive shaft which is driven continuously by the

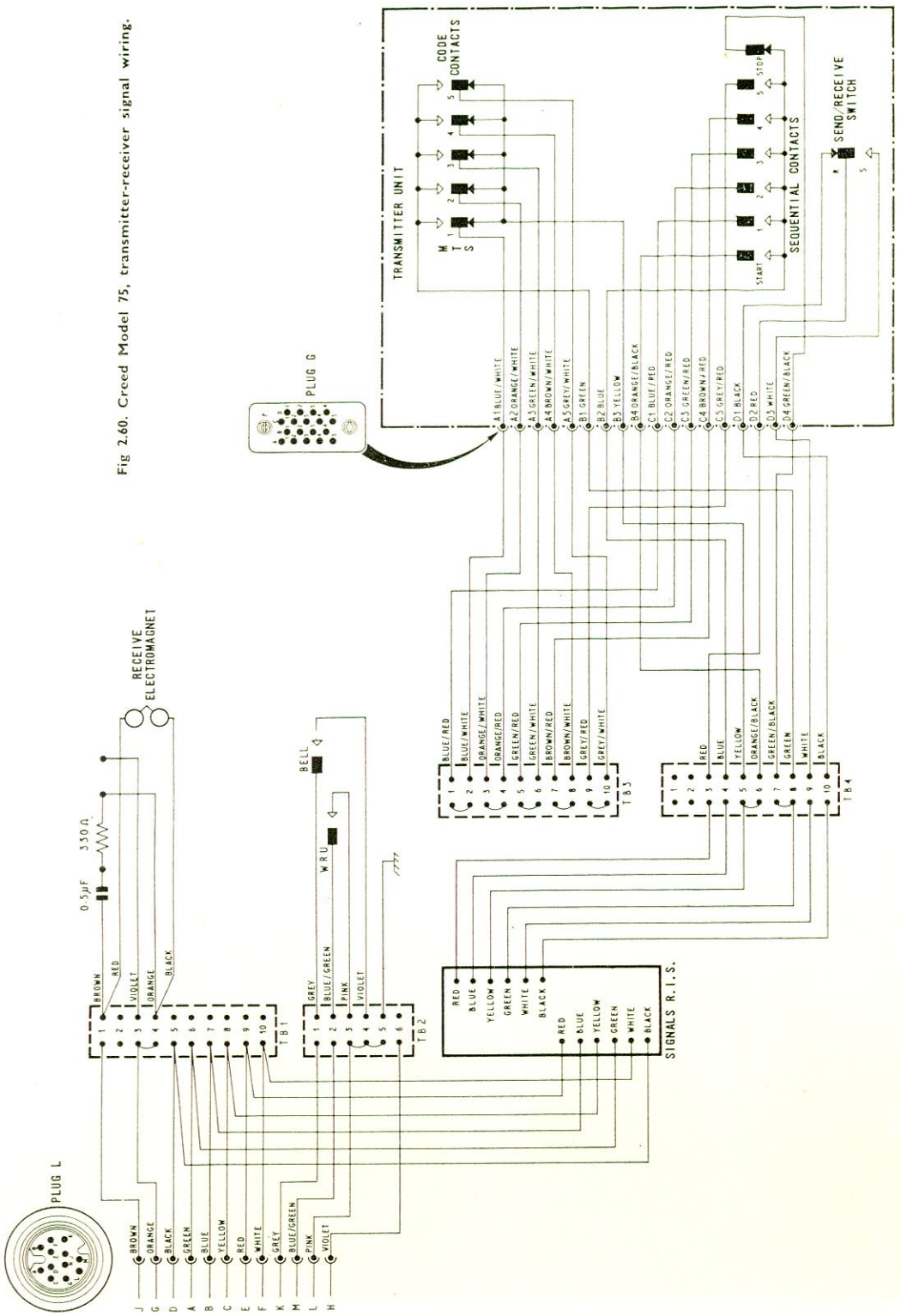


Fig 2.60. Creed Model 75, transmitter-receiver signal wiring.

electric motor. Power for the keyboard is derived from the translator camshaft which also operates the multi-contact transmitter unit.

UNIT FUNCTIONS

Electromagnet

This is a miniature polarized electromagnet of conventional design with a side-stable vertically-pivoted armature which executes a series of movements between its marking and spacing stops for each incoming character. A pair of centralizing springs is linked to the armature for double-current operation to reduce the side-stable forces and increase the sensitivity of the magnet. For single-current operation a second pair of springs is connected to the armature and tensioned so as to bias the armature against the spacing stop during "no current" elements of incoming signals. The frame on which the single-current springs are carried can be moved manually to vary the degree of mechanical bias on the armature.

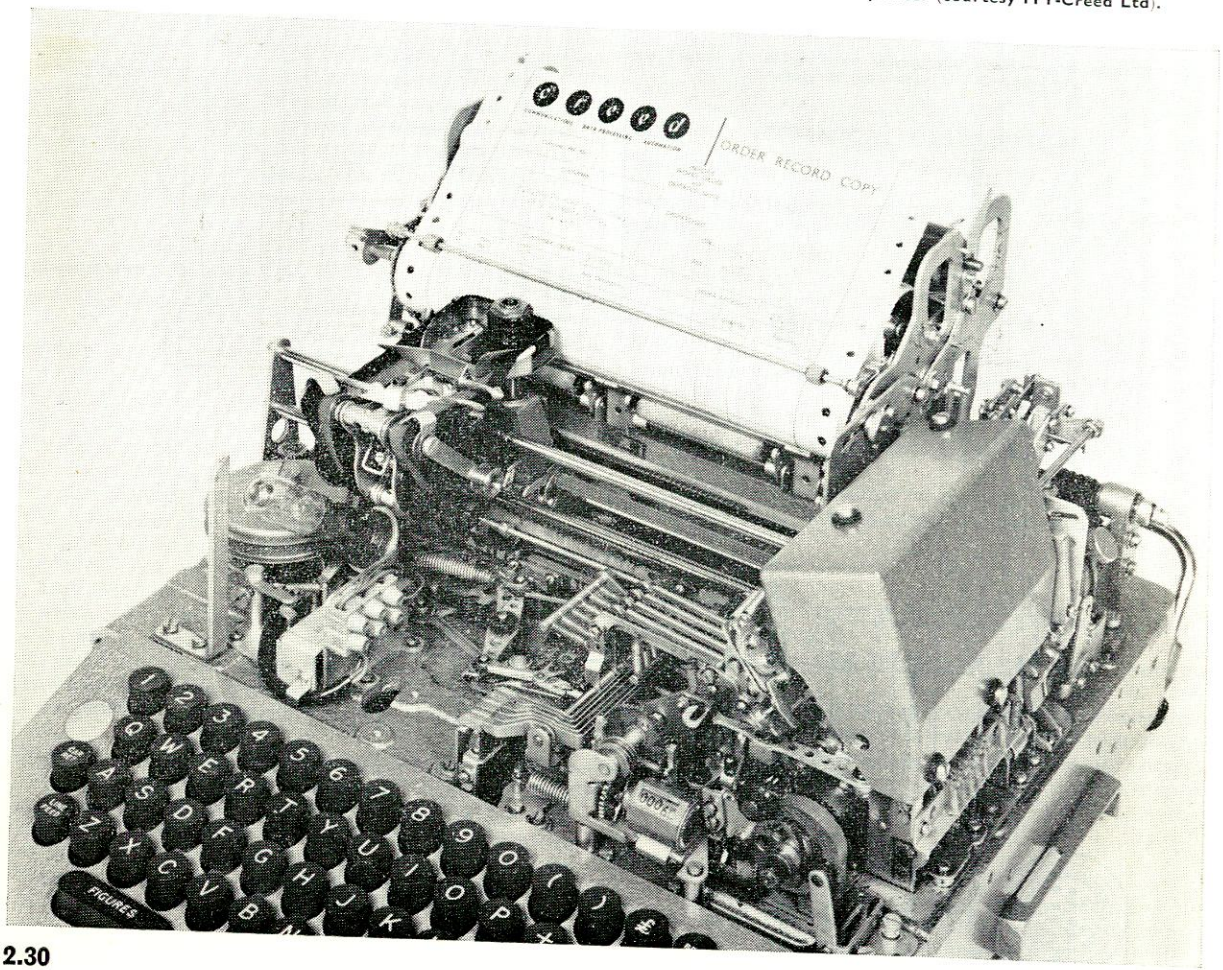
The first mark-to-space transit of the armature has two simultaneous effects; it trips the motor switch, so starting the motor, and it releases the selector unit clutch allowing the selector camshaft to make a single revolution.

Selector Unit

The main function of the selector unit is to convert the incoming signal combination into a static setting on one or other of two sets of five pins located in the translator unit. The selector unit consists primarily of a striking mechanism for these pins, together with a means of traversing this striking mechanism along the lines of pins. Both mechanisms are driven by cams on the selector camshaft. An interposer controlled by the receiving electromagnet can block the striking action and so prevent a particular pin from being set.

If the first code element is a mark the interposer permits the striker to push the first pin inwards where it is retained by a spring. If the signal is a space, however, the interposer will block the forward movement of the striker and so prevent the pin from being set. While the striker is moving across to take up position in front of the next pin, the next code element is being received and the decision as to whether it is a mark or space is taken. After the fifth code element has been

The Model 75 teleprinter (courtesy ITT-Creed Ltd).



registered, a trip linkage operated from the selector shaft retention lever releases the translator camshaft.

Other mechanisms included on the selector unit are:

(*a*) the greater part of the automatic motor switch operating mechanism,

(*b*) a device used on single-current working for automatically disengaging the electro magnet from the selector, and

(*c*) an orientation device by means of which the selection instant can be varied by ± 70 per cent of a code element length

For dual-speed machines the selector unit can also incorporate a manually-operated two-speed gear-box.

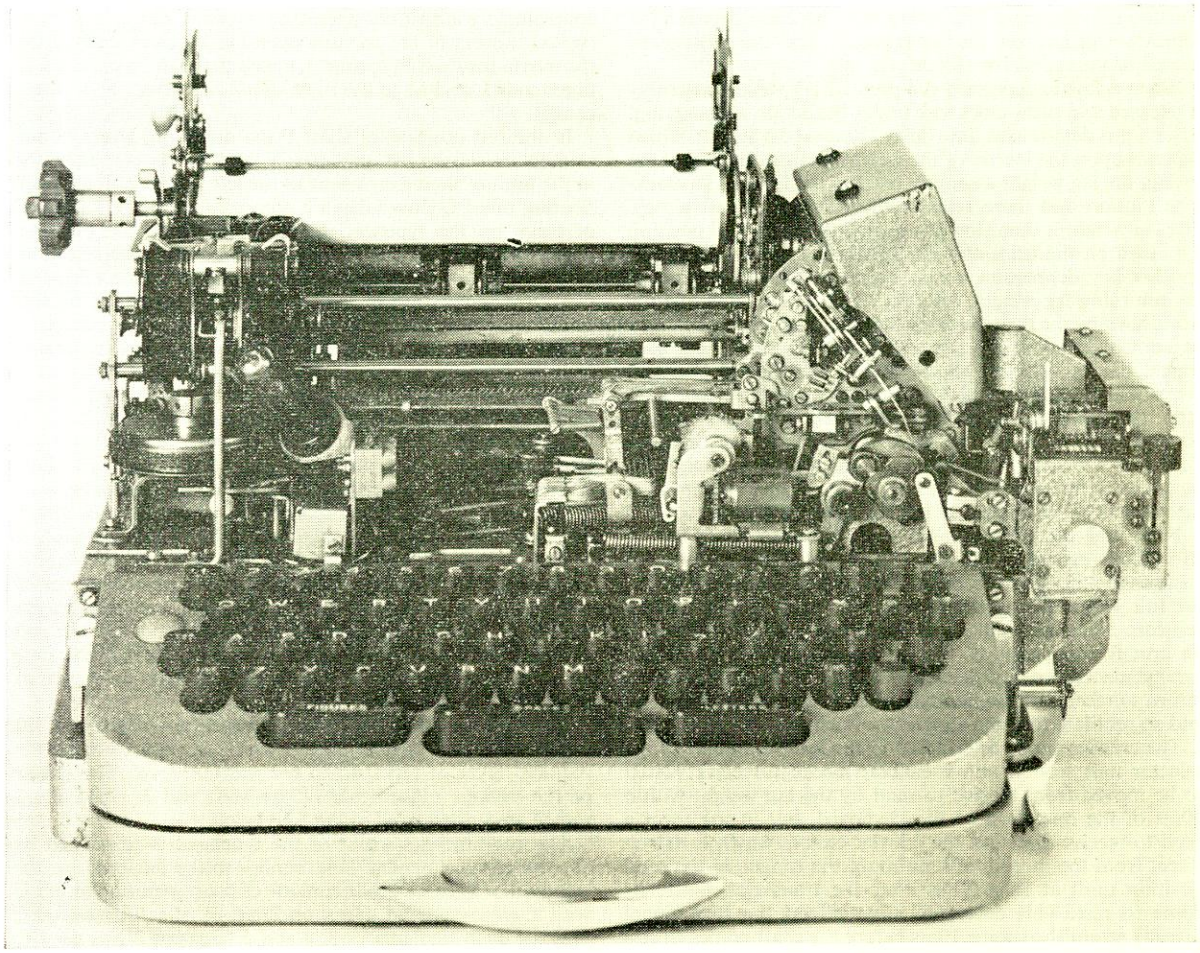
A time relay device, comprising a crawler clutch, is linked to the translator unit lag weight mechanism by shaft. These parts, whose operation is outlined below in the section headed "Translator Unit", act to hold the send-receive switch tongue in the send position if the keyboard operator is transmitting at a speed approaching that of cadence speed, and also to delay the return of the switch tongue by at least 20ms after the last character has been transmitted.

Translator Unit

The main function of the translator unit is to examine the code setting created at the pin-box by the traversing pecker controlled from the selector unit, and then to convey the result of this examination to the aggregate motion unit which decides on the basis of this information which of the types in the typehead will be impressed on the paper.

Simultaneously with the examination of the pin-box setting on behalf of the aggregate motion unit, another examination of the pin-box is taking place to establish whether the particular code setting corresponds to any of the non-printing functions such as "carriage return". If this second inspection shows the code to be a functional one the printing and feeding actions are automatically inhibited and the appropriate function is carried out. The typehead is of course positioned for every incoming character, but in the case of non-printing functions a blank type is brought round to face the paper.

The Model 75 with perforator, covers removed.



The following mechanisms also form part of the translator unit:

(*a*) linkages to operate the non-printing functions such as "carriage return" and also prevent the typehead feeding or printing on receipt of the "all space" combination,

(*b*) the transmitter contact bank, including the send-receive switch,

(*c*) the case shift control mechanism,

(*d*) the lag weight mechanism, and

(*e*) the cam which provides power and controls for the reperforating attachment and the tape reader attachment, if fitted.

The lag weight mechanism referred to in paragraph (*d*) above is rendered necessary because the same 130ms revolution time camshaft is employed to drive both the transmitting and receiving sections of the machine. With a conventional teleprinter there are separate drive shafts for transmission and for reception, the receiving shaft being driven faster (130ms cycle time) than the transmitter (150ms cycle time) to maintain synchronism with the distant station. If this synchronism is to be maintained in a similar manner with the Model 75 Teleprinter, the stop signal, which would otherwise be only 10ms long, must be lengthened by a device which operates independently of the translator shaft. This is done by introducing a time delay of some 20ms between the depression of any key on the keyboard and the subsequent release of the translator clutch.

When a key is depressed the pivoted lag weight assembly is released and turns clockwise under the action of its spring. After a pre-determined time delay (20ms at 50 bauds), which depends upon the inertia of the weight and the tension of the spring, the lag weight assembly reaches the limit of its clockwise motion and there releases the translator shaft clutch. The lag weight is then slowly returned to its original position by a cam on the translator shaft, taking 130ms to do so. If another key depression occurs before 130ms have elasped, the returning lag weight will find its retaining latch already withdrawn by the depression of this key. The weight will now be controlled solely by the contour of its slow reset cam which, having returned the weight to its original position, drops sharply away so allowing the lag weight to rotate and, after the 20ms delay, release the translator shaft again. It can now be seen that however quickly the operator depresses a particular sequence of keys a 20ms delay will be added to the natural 130ms cycle time of the transmission mechanism by the inertia of the lag weight mechanism.

Now that the cycle time of the translator shaft has in effect been extended, all that is now necessary to do is to ensure that the send-receive switch remains set to send for the full 150ms period required for 7½ unit, 50 baud transmission. Since the send-receive switch itself is controlled by an arm forming part of the lag weight assembly, if other arrangements were not made the tongue of the switch would return to receive at the same time as the lag weight was reset and so mutilate the stop signal by clipping it short.

The crawler clutch referred to in the last paragraph of the selector unit section above enables the send-receive switch to be moved from receive to send by the lag weight within 20ms of the operation of the keyboard, but in the reverse send-to-receive direction the crawler clutch, which is driven direct from the motor, will maintain the tongue in the send position until at least 20ms after the translator shaft has come to rest. This delay will thus extend the stop signal already established some 10ms before the shaft comes to rest until, under the normal keyboard operating conditions, the next key is depressed. If no further keys are operated the send-receive switch tongue will slowly move back to receive after the translator shaft has come to rest and take some 80ms to do so.

Aggregate Motion Mechanism

This mechanism is located on the main base between the translator unit and the spring drum unit. It consists of two similar but independent arrangements of links and rods which act together so as to control the lift and rotation of the typehead and so bring the selected type round to face the paper. See **Fig 2.61**.

The vertical movement of the typehead is under the dual control of a pre-set case shift mechanism, and of linkages associated with element No. 2 of the code combination created on the translator unit pin-box by the incoming signals. These two elements acting together cause the typehead to be positioned so that one of its four layers of types is brought up to the printing point.

The components concerned include rack A, idler gear B, gear C fixed to splined shaft D, gear E and rack F, links G, H, J and KT, and rods L and M. The two rods L and M are controlled by individual operating levers of which lever N is typical. Levers N are in turn operated by cams carried on the translator shaft P, spring O, acting through links H and J, urges rods L and M to the right so holding levers N on their cams.

In the rest position of shaft P the operating levers N are at their maximum lift, and rods L and M are consequently at the limit of their movement to the left. The position which floating pivot Q now takes up corresponds to the top layer of types on the typehead being in line with the printing point. When shaft P is released at the end of the selection cycle, the levers N attempt to turn under the action of spring O. Whether they are in fact able to do so depends on the position of case shift latch R and of the selecting pin associated with element 2 of the incoming code combination. If latch R is in the "figures" position (as illustrated) and selecting pin No. 2 is at space, both levers N will rotate and rods L and M will both move to the right. If latch R is in the "letters" position (ie blocking the path of lever N) and pin No. 2 is at space, only rod M will move and link KT will turn counter-clockwise around what has now become a fixed pivot at the end of rod L. The reverse of this action takes place if rod M is blocked and rod L is free to move.

The purpose of linkages KT, J, H and G is to combine the movements of rods L and M into a single movement of rack A. Since pivot Q is sited on link KT so that length K : T : : " : 1 and since the range of movement of shift rod L and code No. 2 rod M is the same, there will be four possible positions of pivot Q disposed equally as shown in **Fig 2.62**.

The positions of pivot Q correspond to 4 degrees of lift at rack F and it is this motion which is used to bring the required layer of types up to the printing level. The effects of the various movements of the shift rod L and code 2 rod M are summarized in **Fig 2.63** below.

The rotating movement of the typehead is controlled by another arrangement of links similar to the one used for the selection of type layers. It consists of four operating levers U with their associated cams on shaft P, the four selecting pins for code elements L, 3, 4 and 5 (element 2 was used to

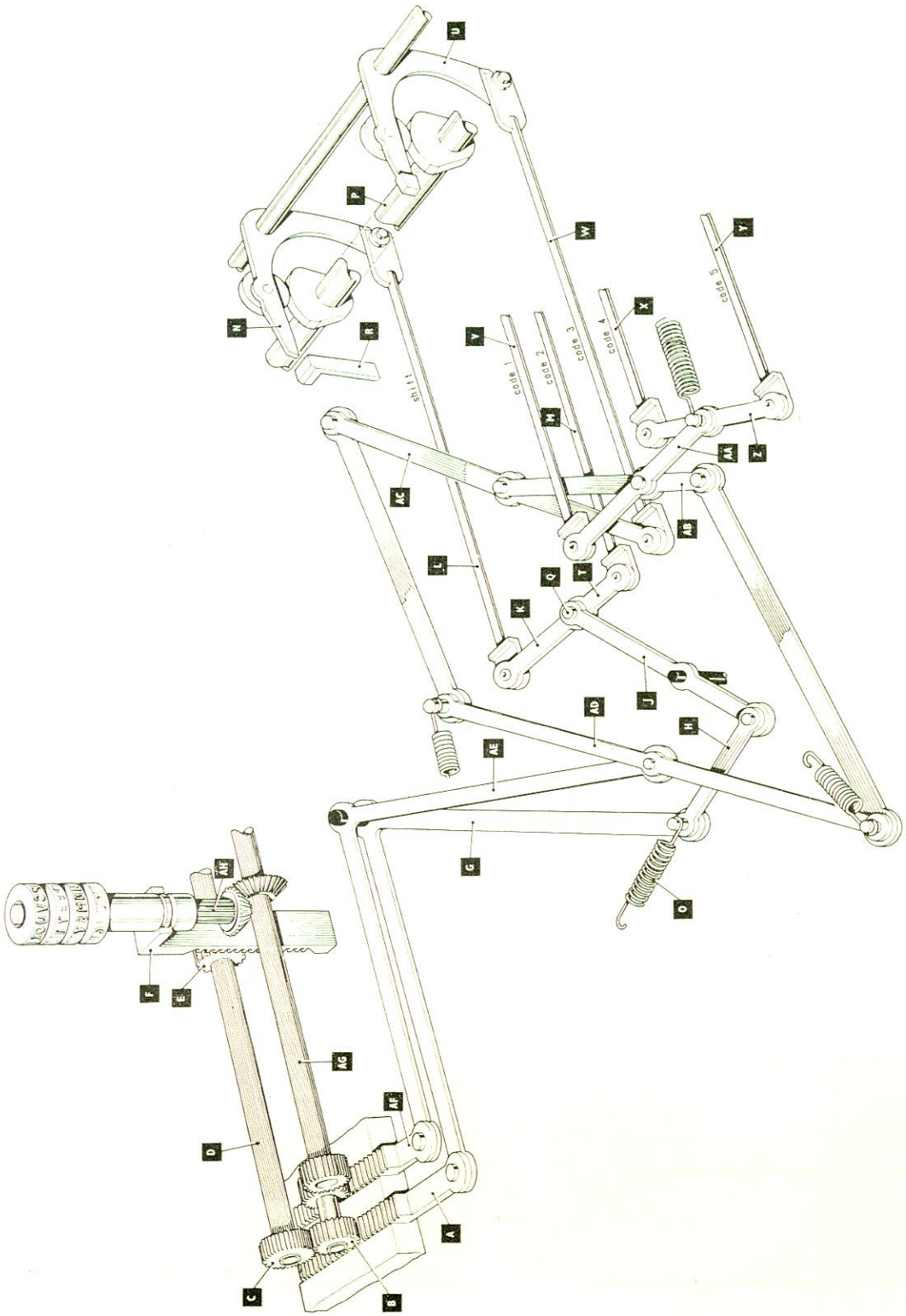


Fig 2.61. Model 75, aggregate motion mechanism.

control lift), links V, W, X and Y, links AA, AB and AC connected via AD to AE, rack AF and splined shaft AG linked by bevel gears to the vertical splined shaft AH which controls the rotation of the typehead. The bevel gear associated with splined shaft AG, and spur gear E associated with splined shaft D, are of course free to slide along their respective shafts as the typehead traverses the printing line.

The cams on shaft P that control the rods associated with code elements 1, 3 and 4 each produces a $\frac{1}{2}$in left-to-right movement when a space setting is read off the selecting pins. The cam associated with rod Y differs from the others in that it gives only a $\frac{1}{4}$in movement when a space is registered on pin 5.

Since each of these four rods associated with typehead rotation can have marking (ie blocked) or spacing (ie free to move) actions there are 16 possible positions all of which combine at lever AE. Rack AF and splined shafts AG and AH convey the setting on lever AE, converting it in so doing into clockwise or counter-clockwise rotation of the typehead so bringing one of the 16 types on a particular layer round to the printing point.

The direction and degree of movement that each of these rods can impart to the typehead is set out in **Table 1** below. In this table, and in the explanation that follows, a clockwise rotation is considered as being positive, and a counter-clockwise rotation is considered negative.

TABLE 1

Code	Movement on Space	Typehead rotation	Degree of movement
1	$\frac{1}{2}$in	CW	+4 characters
3	$\frac{1}{2}$in	CCW	−8
4	$\frac{1}{2}$in	CW	+2
5	$\frac{1}{4}$in	CW	+1

CW — clockwise CCW — counter-clockwise

Reference to **Fig 2.61** will show that it is only on spacing elements of the code that the control rods V, M, W, X and Y can move to the right. Consider, for example, the combination for letter "B" which is mark, space, space, mark, mark, Element No. 2 can be disregarded in this context as it is associated with the lift operation, and so also can elements 1, 4 and 5 as they are marks and consequently do not permit their associated control rods to move. The only effective element from the rotational point of view is, therefore, the space on No. 3. **Table 1** above shows that $\frac{1}{2}$in movement on this rod will produce a counter-clockwise rotation equivalent to eight radial positions on the typehead.

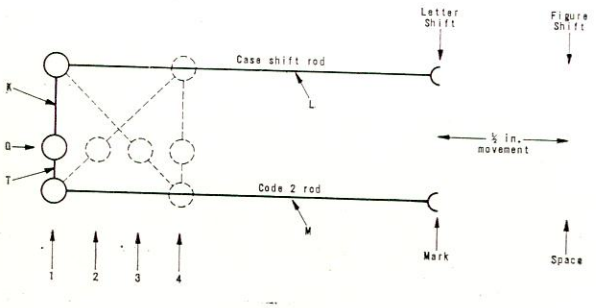


Fig 2.62. Aggregate motion, lift linkages.

Fig 2.62 below shows that the position in which the letter "B" is located is 180 degrees from the printing point. The "minus 8" movement brought about by the $\frac{1}{2}$in left-to-right movement of rod M has now, therefore, brought letter "B" round to face the paper.

When more than one spacing element occurs among elements 1, 3, 4 and 5 of a particular code combination, the subsequent movement of the typehead can be determined by taking the algebraic sum of the individual effects of the "spacing" control rods concerned.

As an example consider the code for letter "Z" which is mark, space, space, space, mark. Disregard element 2 and all the marks. Element 3 and element 4 are spaces and cause −8 and +2 movements respectively. The algebraic sum of these two movements is −6. Reference to the typehead layout chart above will now show that a counter-clockwise rotation of six type positions magnitude will bring the letter "Z" round to the printing point.

Although the vertical and rotational movements of the typehead have been described separately, they are produced by the same camshaft (P, **Fig 2.61**) and therefore occur together. The combined effects of both the lift and rotation mechanisms can be assessed by combining the information given in **Tables 2** and **3** which are based on the CCITT International Telegraph Alphabet No. 2.

TABLE 2

Code −2 - - -	Shift	Typehead lift (in layers)	Layer brought up to printing point
−M - - -	letters	0	1
−M - - -	figures	1	2
−S - - -	letters	2	3
−S - - -	figures	3	4

TABLE 3

Code 1-345	Typehead movement in characters	Character brought to printing point			
	layer	1	2	3	4
m-mmm	0 CW	ltrs*	ltrs*	X	/
m-mms	1 CW	K	(	F	%
m-msm	2 CW	Q	1	Y	6
m-mss	3 CW	U	7	S	'
s-mmm	4 CW	V	=	M	.
s-mms	5 CW	C	:	N	,
s-msm	6 CW	P	O	H	£
s-mss	7 CW	I	8	space*	space*
m-smm	8 CCW	figs*	figs*	B	7
m-sms	7 CCW	J	bell*	D	WRU*
m-ssm	6 CCW	W	2	Z	+
m-sss	5 CCCW	A	-	E	3
s-smm	4 CCW	G	@	0	9
s-sms	3 CCW	R	4	car ret*	car ret*
s-ssm	2 CCW	L	)		5
s-sss	1 CCW	line feed*	line feed*	all space*	all space*

Type positions indicated by the * are blank, as they correspond to non-printing functional codes.

Keyboard and Transmission

For transmission the machine can be fitted with a keyboard for mechanically selecting the 5-unit code appropriate to the depressed key, and a transmitter for converting this code selection into a sequence of five pulses to which are automatically added the start and stop signals before the complete sequence is transmitted to line via the send-receive switch.

An original feature of this type of keyboard—referred to as the K-type—is that it has no separate transmitter or transmit camshaft associated with it, but employs the receive camshaft to drive a multi-contact transmitter located above the translator unit.

The keyboard unit consists of an arrangement of keybars pivoted above and at right angles to a group of five combination bars carried in a clamp plate. Each combination bar is urged to the right by a spring, but held at rest on a latch assembly common to all five bars. This latch is released by the depression of any key so allowing the combination bars, which have a series of irregularly-disposed square teeth along their upper edges, to slide to the right.

Combination bars required to set up a space condition are prevented from moving by one of their teeth engaging the left-hand side of the selected key. A mark combination bar, on the other hand, does not have a tooth at the point immediately preceding the selected keybar and can, therefore, slide to the right. This sliding movement operates a bellcrank linked to one of the six vertical rods.

Linkages convey the movement of these vertical rods to the translator unit pin-box and cause the associated pin to be pushed inwards to record a mark condition. The front vertical rod is pushed up by a trip bar whenever any key is depressed, and it is the movement of this rod which releases the lag weight and thus the translator shaft clutch.

The code setting established on the translator unit pin-box is then sensed by the selector code plates and it is the blocked or free movements of the associated levers which determine the mark or space condition on the transmitter contact assembly.

Answer-Back

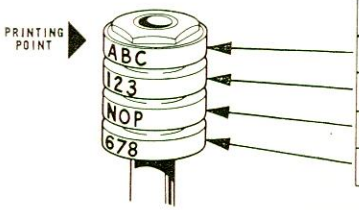
This unit takes no part in the operation of the machine until activated by an incoming "Who-are-You?" signal. It then automatically signals the call sign of the home station back to the enquiring machine, so assuring the calling operator that he is connected to the correct station and that it is operating correctly. The facility can also be used to obtain a form of receipt for a message sent to an unattended machine.

The answer-back unit has capacity for up to 20 printing or functional characters, generally allocated as follows: CARRIAGE RETURN, LINE FEED, LETTER OR FIGURE SHIFT, up to 14 letters or figures comprising the station call sign, CARRIAGE RETURN, LINE FEED, LETTER SHIFT. The individual characters are generated from the interchangeable contoured coding elements (referred to as "wards") which are carried on a drum which is ratchet fed from the translator unit. The drum is rotated so as to present each ward in turn to a series of sensing levers which take over the control of the transmission mechanism at a point adjacent to the push rods and simulate the movements of these rods so as to set up on the translator pin-box the combination dictated by the contour of the ward. The answer-back unit then automatically releases the main translator shaft which subsequently revolves once to transmit the character to line. The answer-back then repeats this sequence a further 19 times to transmit the remainder of the call sign to line, before coming to rest and relinquishing its control of the translator mechanism to the keyboard.

The local answer-back unit can also be brought into operation by depressing the "Here Is" key on the keyboard. The unit then transmits the home station call sign and comes to rest. The "Here Is" key is linked directly to the answer-back trip mechanism and does not transmit a character to line.

Reperforating Attachment

This optional attachment can record incoming and outgoing messages on an $\frac{11}{16}$ in-wide paper tape, simultaneously with the production of the equivalent page copy. The perforated



LAYER	SHIFT ROD	CODE 2
1	letters	mark -
2	figures	mark -
3	letters	space -
4	figures	space -

Fig 2.63. Typehead, layer section.

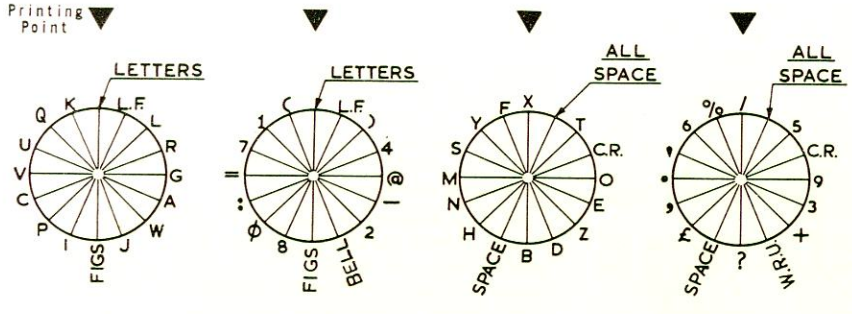


Fig 2.64. Typehead, layer arrangement.

tape forms a permanent record of all the code signals involved in a particular message in a form suitable for storage and for subsequent retransmission by a tape reader. The mechanical local record facility of the Model 75 machine enables it, when fitted with this attachment, to function as a keyboard perforator and also to produce a printed check copy of the material perforated in the tape, without it being necessary to provide a signalling battery.

The reperforating attachment employs a fixed punch block beneath which code selecting bars operated from the translator unit are positioned in accordance with the code combination registered on the pin-box. Once these selecting bars have been positioned they are lifted by a punching arm driven from an eccentric block carried on the translator shaft. Marking selecting bars now engage their associated punches to drive them through the paper tape; spacing bars are withdrawn clear of their punches which, therefore, remain at rest. The return stroke of the punching arm provides power to withdraw marking punches from the paper and also to operate the ratchet which drives the tape feed mechanism.

INTERNAL CIRCUITS

The internal signals wiring of the Model 75 Teleprinter is shown in **Fig 2.60**.

The receiving electromagnet consists of two 110Ω coils which are wired in series and have a combined inductance of 4½H measured at 50cps, 40mA. The leads from the electromagnet are taken to terminals 1 and 4 of terminal block TB1 and thence to line via pins J and G on the 12-way signals plug.

Operating currents and voltages are 120V, 40mA for single-current circuits, and +80V, 0, −80V, 20mA for double-current circuits if 2kΩ of the current limiting resistance is shunted by a 2μF capacitor. Without this capacitor the current must be at least 25mA.

The mark, tongue and space code contacts are wired individually via plug G back to terminal block TB3 (located beneath the main base) whose straps link the tongues to the associated moving element in the sequential contact bank. The fixed contacts in the sequential bank are commoned at the transmitter and go to line on pin B of the 12-way signals plug L via terminal block TB4 and the RIS unit. The send-receive switch is linked to terminal block TB4 via plug G and goes to line on pins F, D and E for send-receive and tongue respectively.

Fig 2.60 shows the code contacts 1, 2, 3, 4 and 5 in the position which they take up when the translator shaft is at rest. All the tongues are resting on their spacing side and are electrically connected via straps on terminal block TB3 to the moving blades of the associated sequential contacts. The space code contacts (the lower ones on **Fig 2.60**) are in parallel with each other and with the moving blade of the start contact; the mark code contacts (the upper ones on **Fig 2.60**) are similarly in parallel with each other and with the moving blade of the stop contact which is always made at rest.

Shortly after the translator camshaft starts to rotate, the five moving blades of the code contact bank move to the mark contacts and then either return to space or remain at mark depending upon the code combination established on the selecting pins. This action takes place while the initial stop and start signals are being transmitted. The code contacts then remain in the positions to which they have been set for the remainder of the cycle, during which other cams on the translator shaft operate the sequential contacts. Marking code contacts are finally returned to the rest spacing position about 2ms after the translator shaft comes to rest.

It is important with double-current circuits to ensure that the transmitter sequential contacts are adjusted so that there is a short interval between the opening of each contact and the closing of the next. If this is not done it is likely that the signalling supply will be momentarily short-circuited during transmission. Although this momentary condition is unlikely to damage the supply it may result in the transmission of a code combination that has been mutilated by the discharge of smoothing capacitors in the signalling rectifier set. A protection lamp in each leg of the signalling supply will safeguard the supply and slow down the discharge of any capacitors.

EXTERNAL CIRCUITS

General

When external circuits for the Model 75 Teleprinter are being designed or modified the following special features of the machine should be considered.

(*a*) Since the contacts of the transmitter are driven from cams carried on the main translator camshaft, and read off the code combination direct from the code selecting pin-box, these contacts are operating while the machine is receiving as well as while it is transmitting. It is therefore necessary to inhibit the transmitter electrically during reception to prevent re-transmission of received signals.

(*b*) As a mechanical local record is always present when the Model 75 is transmitting, whatever local record circuitry was required previously must be disconnected when a Model 75 is installed. With a conventional double-current switched simplex circuit, for example, this can be done by simply omitting the leak resistor, but with single-current loop circuits that have two or more transmitters and electromagnets in series, the electrical local record cannot be dispensed with so easily as the line current passes through every electromagnet in the circuit.

To cater for these single-current applications all standard Model 75 machines are fitted with an armature throw-out facility which can be adjusted so that the trip action from the keyboard to the translator unit will automatically disconnect the electromagnet armature from the selector unit before the combination for the selected key can be transmitted. The electromagnet can now respond to the signals transmitted through it, but the movements of its armature will not be conveyed to the selector. The armature is automatically reconnected to the selector within 130ms of the end of the transmission. This armature throw-out facility is of course normally adjusted to an inoperative position for double-current applications.

(*c*) The implications of this mechanical local record feature should also be considered when a fault has to be located. With the Model 75 an accurate local copy is not necessarily proof of accurate transmission. The mechanical local record feature also precludes the use of duplex circuits.

(*d*) The armature throw-out mechanism mentioned in paragraph (*b*) above also controls the send-receive switch. The tongue of this switch moves to send immediately a key is depressed, ie before the start signal is transmitted, and returns slowly to receive after the end of the stop signal. This delayed return of the send-receive switch tongue to receive, unlike the armature throw-out facility, cannot be made inoperative.

The effect of this slow return feature on a switched simplex circuit should not be overlooked. If on a one-wire circuit of this kind the transmitting operator maintains a keyboard speed which closely approaches cadence speed, the send-receive switch will remain in the send position until either the operator reduces speed or the transmission ends. Because of this continuous send condition it is not possible for the distance station to break in on the home station's transmission.

(*e*) A mechanism is provided to protect the machine from damage that could occur if an operator attempts to break in on an incoming message by operating his keyboard. The danger occurs when the local operator releases the local translator unit by operating the keyboard at the instant when his selector unit is in the act of setting up a marking combination in the pin-box. The subsequent traversing movement of the pin-box which occurs at the very beginning of the translation cycle could cause the pecker to be trapped against the side of an adjacent selecting pin which happened to be in the space position.

This combination of circumstances is guarded against by a break-in mechanism which will automatically set the selecting unit retention hook up to the space position and hold it there until the crawler clutch resets. Although this mechanism will not prevent the release of the translator unit while the selector unit is responding to incoming messages, it does prevent the pecker striking forward and so eliminates the possibility of a foul between it and a spacing selecting pin in the traversing pin-box.

(*f*) The electromagnet armature is fitted with a pair of centralizing springs that increase the sensitivity of the electromagnet by reducing the changeover force and reducing the impact on the stops which limit the movement of the armature. The anchor points for these springs are on an adjustable plate which is positioned so as to produce a neutral bias on the armature. A second pair of springs is connected to the armature for single-current applications. These are anchored on an adjustable carrier which is set manually to produce the required degree of mechanical bias. For double-current working, this second pair of springs is disconnected at the armature end and left hanging from the carrier.

(*g*) The transmitter contacts are adjusted differently for single- and for double-current working. To eliminate bias distortion on single-current circuits the closing times of the sequential contacts should be adjusted so that one closing time begins just when the preceding one ends. In practice, these single-current closing times are often adjusted to overlap slightly to ensure that there will be no breaks in a block signal.

For double-current applications the closing times are adjusted so there is a distinct break between the opening of one contact and the closing of the next. If this were not done, the signalling supply may be momentarily short-circuited. While a short-circuit of this duration is unlikely to damage the supply, it may cause a character to be corrupted by the discharge of smoothing capacitors in the signalling rectifier. It is good practice to include a protection lamp in each side of the signalling supply. This will not only protect the supply and the transmitter contacts but also reduce the chances of a corrupted signal by slowing up the discharge of the smoothing capacitors.

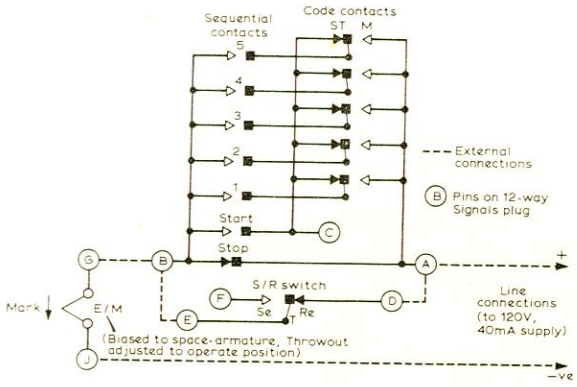


Fig 2.65. Single current loop circuit.

Single-current Operation

The external wiring for a typical single-current loop circuit employing 120V, 40mA signalling is shown in **Fig 2.65.**

The electromagnet must be mechanically biased to space and the armature throw-out mechanism adjusted to the operating position so as to prevent the electromagnet from tripping the selector unit, and so corrupting the mechanical local record.

The send-receive switch is used to prevent received signals from being re-transmitted along the send leg of the circuit. Its tongue and receive contacts are connected across the transmitter and the send contact disconnected. Thus although the received signals are continuously reproduced on the transmitter, none of the signals can affect the line circuit. Note, too, that the five space code contacts and the start contact are all left disconnected for single-current working.

The 0·5μF + 330Ω network wired to terminal block 1 should not be used on single-current circuits.

Double-current Operation

A typical double-current two-wire simplex circuit is shown in **Fig 2.66** and a typical switched simplex circuit in **Fig 2.67.** In both circuits the convention of negative battery to line for mark is used. No leak resistors are required as the local record is obtained mechanically.

In the two-wire circuit in **Fig 2.66**, the send-receive switch and transmitter contacts are interconnected so that, although during periods of reception the transmitting contacts are operating continuously, a nearly-continuous mark signal is transmitted to the distant electromagnet. This arrangement has been adopted to prevent the slow return of the send-receive switch in the send to receive direction from leaving

the send line without a signal and so creating a possible half-tone condition on voice-frequency line equipment.

The 0·5μF + 330Ω spark quench circuit can be used, if required, on these two double-current circuits.

DISMANTLING INSTRUCTIONS

The instructions in this section are presented in a convenient sequence for dismantling a complete machine for a major overhaul. The detailed instructions for each unit, however, are given in such a way that it is possible to dismantle the majority of the individual units on their own, as required. The exceptions to this procedure are the type-head carriage, function bar, translator and platen units. The translator unit, in fact, cannot be dismantled or reassembled without prior removal of most of its adjacent units.

The disturbance of some adjustment points is unavoidable when dismantling, although the procedure given avoids this as far as possible. To obviate any excessive re-adjustment which might otherwise be unnecessary, it is essential that units are mounted firmly against their abutments when reassembled to the machine.

When reassembling a complete machine it is advisable to carry out the reassembly and necessary adjustments in stages.

In the following instructions it is assumed that the main teleprinter cover has already been removed, thus allowing full access to the units concerned.

When carrying out the instructions in this section it is important to note the position of any shims or washers dismantled, and also the length of screws as they are removed.

Always remove the signal and power plugs from the rear of the machine main base before starting to dismantle any part of the machine.

Take extreme care when winding or unwinding the carriage return spring drum as the spring is very powerful. It is advisable to hold a piece of rag in the hand when winding or unwinding the drum.

Avoid moving screws which have been painted red unless a specific instruction to do so is given. Some of these red screws control one-time adjustments set at the initial assembly stage but others have been set to gauges in the factory and cannot be reset easily under field conditions.

To Dismantle the Machine Into Units

1. *Reperforating Attachment*

1.1 Remove the three screws securing the reperforator side cover and the screw that secures the lower (curved) side cover. Take off both covers.

1.2 Remove the three screws securing the reperforator support bracket to the machine main base.

1.3 Slacken the screw securing the punching arm special pivot. Insert a tommy pin through the hole in the punching arm pivot and gently ease the pivot approximately $\frac{1}{4}$in (6·4mm) towards the front of the machine. Remove the tommy pin.

1.4 Withdraw the unit from the machine.

2. *Operation Counter*

2.1 Remove the front two screws. Slacken the rear screw, slide the unit towards the front of the machine and lift it off the main base.

3. *Transmitter Unit*

3.1 Remove the three screws securing the transmitter cover and lift off the cover.

3.2 Disconnect the 18-way signals socket from its plug and carefully pull off the connexions to the Bell and WRU? contacts.

3.3 Dismantle the transmitter unit from the machine by

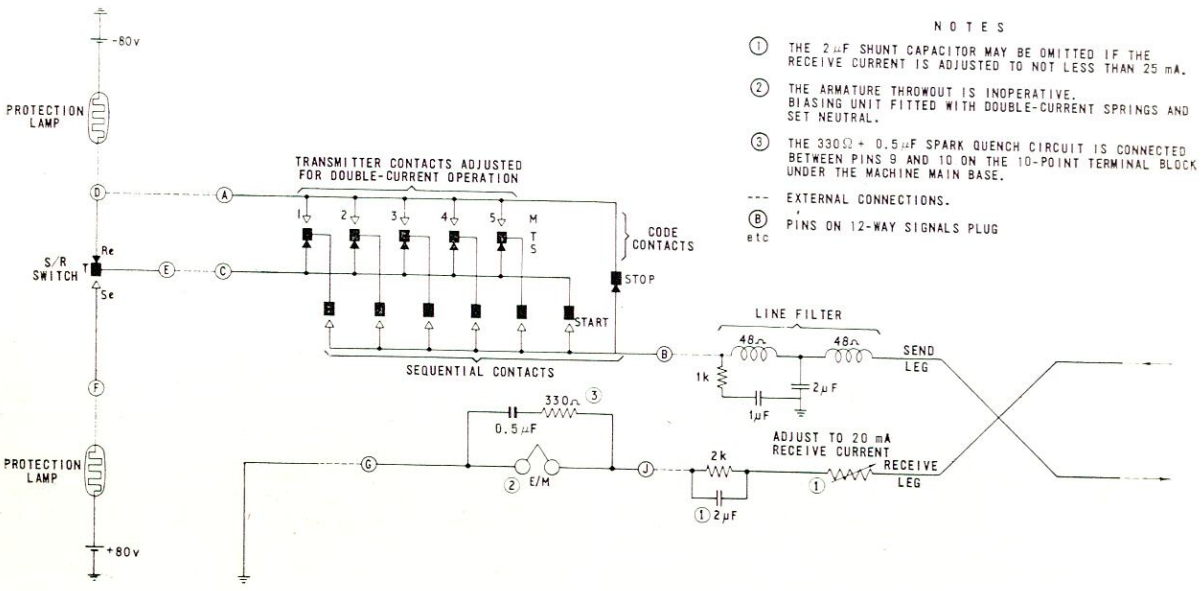


Fig 2.66. Two-wire simplex circuit.

one of the following methods according to the circumstances, taking care not to damage the code contacts and spring assemblies when lifting off the unit.

(*a*) If the transmitter unit only is required to be dismantled, remove the three screws (two on the left-hand, one on the right-hand side) securing the contact mounting plate to the contact plate support and lift off the unit.

(*b*) If it is intended later to dismantle the function bar unit from the machine, remove the four screws (two at each end) securing the contact plate support to the translator unit front and rear frames, and lift off the support together with the transmitter unit.

4. *Answer-back Unit*

4.1 Remove the circlip connecting the top of the transfer lever link to the release lever.

4.2 Remove the three screws and lift the unit off the main base.

5. *Selector Frames Unit*

5.1 Disconnect the answer-back feed pawl spring and swing the feed pawl clear of the selector frames.

5.2 Remove the two screws securing the unit front bearing, and slacken the two screws securing the unit rear bearing. Slacken the trip bar retaining screw sufficiently enough to allow the trip bar to be withdrawn.

5.3 Slide the unit to the left and lift it off the main base.

6. *Keyboard*

6.1 Support the weight of the keyboard with one hand and remove the two screws with the other.

6.2 Lower the keyboard and withdraw it from the main base.

7. *Motor Unit*

7.1 Remove the two screws securing the paper guide plate and lift off the plate.

7.2 Slacken the two screws and remove the rear tie rod.

7.3 Disconnect the motor plug from its socket on the main base.

7.4 Remove the four screws securing the motor base and lift the unit clear of the machine.

8. *End-of-line Indicator and Carriage Return Spring Drum*

8.1 Turn the carriage return spring drum clockwise approximately an eighth of a turn to relieve the tension on the carriage return tape, and disconnect the hook on the tape from its anchor on the spring drum. Allow the spring to unwind gently.

8.2 Remove the end-of-line indicator lamp and disconnect the wiring at terminal block.

8.3 Remove the three screws and lift the unit clear of the main base.

9. *Ribbon Unit*

9.1 If not already done, unwind the carriage return spring drum as described in paragraph 8.1 above.

9.2 Position the typehead carriage in the centre of its traverse.

9.3 Remove the four screws (two at each end) securing the ribbon unit and take off the unit complete with its guide rails and brackets. Take care not to lose the cam roller or its lubricating washer.

Note that the top right-hand screw also secures the function bar unit.

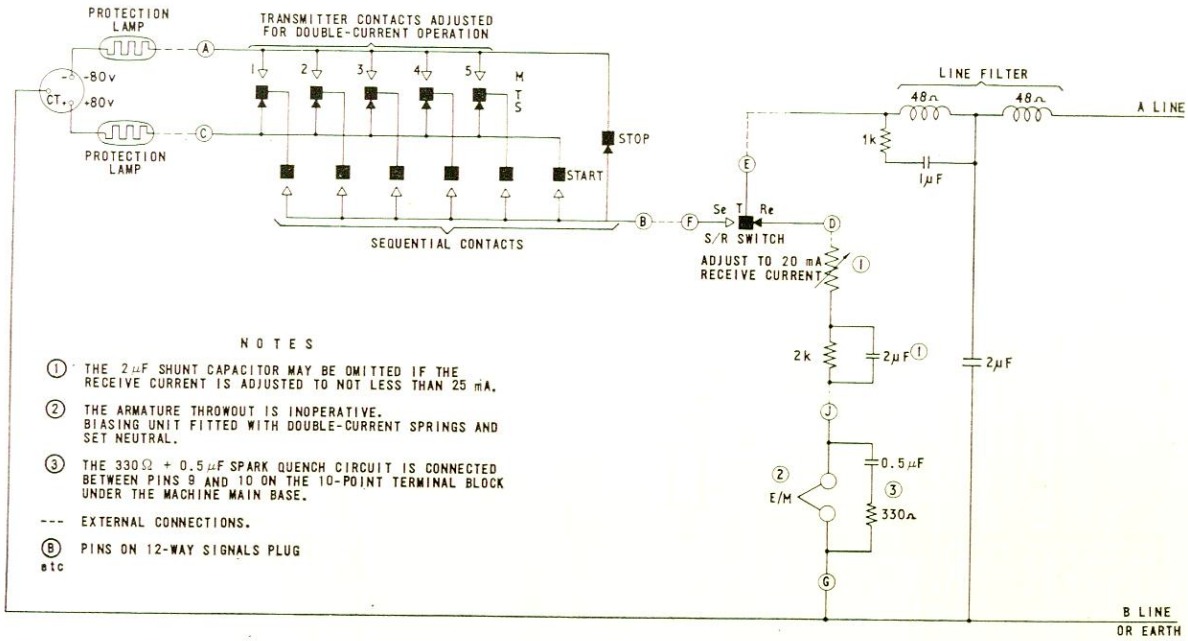


Fig 2.67. Switched simplex circuit.

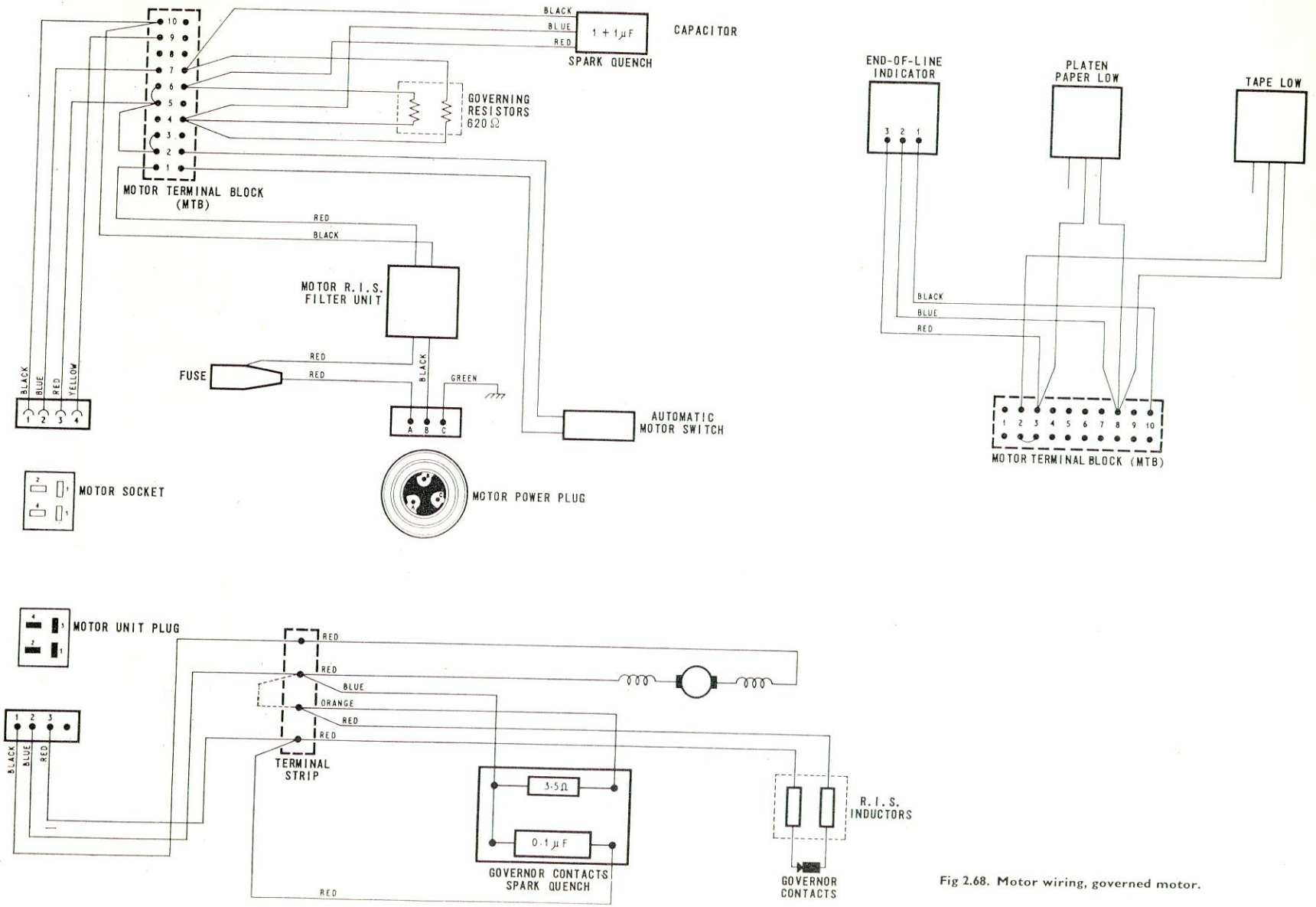


Fig 2.68. Motor wiring, governed motor.

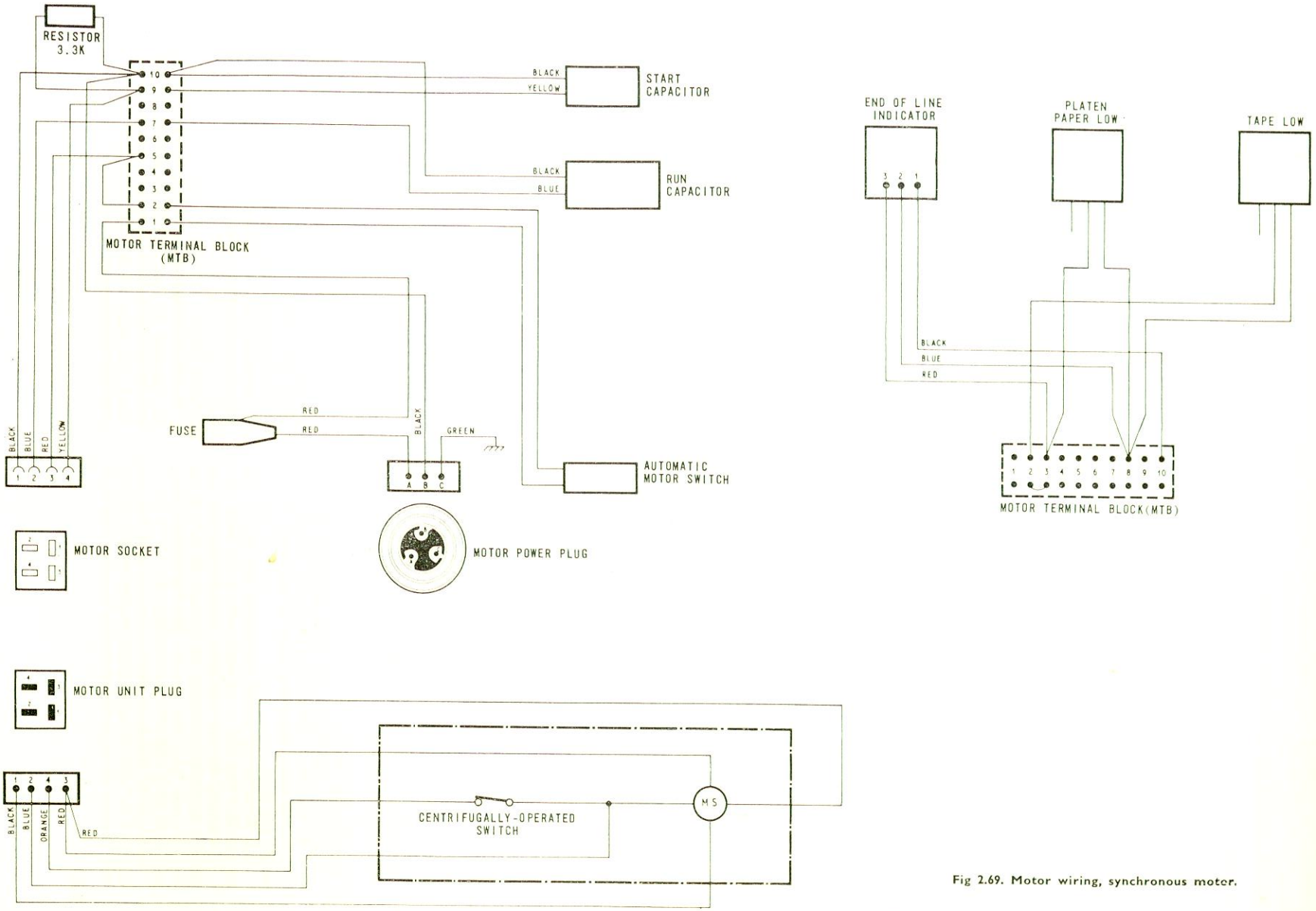


Fig 2.69. Motor wiring, synchronous motor.

10. *Typehead Carriage Unit*

10.1 If not already done, dismantle the ribbon unit from the machine as described in paragraph 9 above.

10.2 Set up any printing combination of the pins, lift the translator clutch abutment and turn the machine by hand until the typehead moves forward to print.

10.3 Remove the two screws securing the print rail coupling.

10.4 Disconnect the carriage feed link by operating the carriage return lever and sliding the link out of its slot.

10.5 Remove the two screws and take off the left-hand typehead bearing block, noting any shims.

10.6 Withdraw the typehead carriage unit carefully to the left and lift it clear of the main base.

11. *Aggregate Motion Unit*

11.1 Remove the left-hand screw securing the traverse pivot bracket to the translator unit front main frame and temporarily slacken the bracket right-hand screw. Carefully lift the left-hand end of the pivot bracket clear of the aggregate motion mechanism and then secure it in this position by tightening the bracket right-hand screw.

11.2 Remove the nut (underneath the main base) securing the aggregate motion levers' main pivot.

11.3 Disconnect the aggregate motion lever springs and the compensator cam lever spring.

11.4 Disconnect the circlips and lift the pushrod assemblies clear of their pivots.

11.5 Carefully withdraw each pushrod from its associated bellcrank lever.

12. *Selector Unit*

12.1 If not already done, disconnect the 18-way signals socket from its plug, and carefully pull off the connections to the Bell and WRU ? contacts.

12.2 Remove the cleats securing the wiring to the translator unit rear frame and the selector unit casting, and move the wiring clear of the selector unit.

12.3 Remove the two screws and lift off the trip shaft together with its bracket.

12.4 Ensure that the translator clutch is in the rest position so that translator clutch bands are free of the selector clutch drum. Remove the three screws securing the selector unit to the main base.

12.5 Disconnect the pecker frame spring and the traverse spring. Remove the screw securing the pecker slide block and lift off the block.

12.6 Slowly and carefully ease the selector unit away from the translator unit and lift it off the main base.

13. *Function Bar Unit*

13.1 If not already done, dismantle the transmitter unit from the machine as described in paragraph 3 above.

13.2 Disconnect the spring from its anchor on the lag weight trip lever.

13.3 Remove the circlip connecting the top of the answer-back trip link to the answer-back trip lever CS.

13.4 Ensure that the translator camshaft is in the rest position and insert a tommy pin through the hole in the function reset bar. This ensures that the function bars remain in place when the unit is removed.

13.5 Lift the translator clutch abutment and turn the camshaft by hand through approximately half a revolution. Depress the extension arm of the function reset shaft on to the push rod to ensure that there is a clearance between the rear end of the function reset bar and the abutment block.

13.6 Remove the four screws securing the unit and lift it off the translator unit.

If the ribbon unit has not already been dismantled, it will be necessary to remove the top right-hand screw in addition, as this screw secures both units.

14. *Translator Unit*

14.1 If not already done, dismantle the following units from the machine.

Reperforating attachment (paragraph 1 above refers)
Selector frames unit (paragraph 5 above refers)
Ribbon unit (paragraph 9 above refers)
Typehead carriage unit (paragraph 10 above refers)
Aggregate motion unit (paragraph 11 above refers)
Selector unit (paragraph 12 above refers)

In addition, if the machine is fitted with a tape reader, it will be necessary to dismantle the keyboard as described in paragraph 6 above.

14.2 Remove the circlip connecting the top of the line feed link with the platen unit right-hand side plate.

14.3 Disconnect the print beam, by removing the screw securing the pin retainer to the print shackle. Take off the retainer followed by its pin.

14.4 Remove the six screws which secure the unit to the main base.

14.5 Remove the screw securing the bracket to the platen unit right-hand side plate and gently lift the unit off the main base.

If the machine has a sprocket feed platen, before attempting to lift the unit off the main base it will be necessary to remove the two screws securing the bracket to the translator unit rear frame and take off the bracket. This is because of the length and position of the sprocket feed change lever. If this is done, refit the bracket to the translator unit rear frame and secure it with its two screws after the unit has been removed.

15. *Electromagnet*

15.1 If not already done, dismantle the motor unit from the machine as described in paragraph 7 above.

15.2 If the machine has been used on single-current operation, disconnect the biasing springs from the electromagnet armature.

15.3 Stand the machine on its back, remove the five screws securing the SRBF cover plate and take off the plate.

15.4 Disconnect the two leads from the electromagnet to its terminal block. Slacken the two screws securing the terminal block to the main base and move the block clear of the magnet base.

15.5 Remove the four screws securing the electromagnet to the main base and withdraw the magnet through the hole in the main base casting.

16. *Platen Unit*

16.1 If not already done, dismantle the motor unit from the machine as described in paragraph 7 above, and remove the bracket which secures the platen unit right-hand side plate to the translator unit rear frame, as described in paragraph 14.4 above.

16.2 Disconnect the print spring mechanism by unscrewing the special hexagonal nut on the spring adjustment link.

16.3 Remove the four screws securing the platen unit to the main base and lift off the unit.

MAINTENANCE

The Model 75 is a very compact unit and consequently some adjustments tend to be a little more difficult to perform than those on the older machines. It should also be appreciated that some adjustments can affect others and the owner is advised to refer to the manufacturer's service manual if anything, other than simple adjustments, is required.

General

1. Remove the signal and power plugs from the rear of the machine main base. Take off the machine cover and inspect the mechanism for the following points.
   (*a*) Visual damage.
   (*b*) Excessive wear of mechanical components.
   (*c*) Lubrication failure, as indicated by the presence of a red powdery substance.
   (*d*) Corrosion.
   (*e*) Charring, overheating or tracking of electrical components.
   (*f*) Faulty insulation or poor termination of wiring.
   (*g*) Loose fixing screws, locknuts or circlips.

2. Using a soft brush, remove all traces of paper fluff, dust and tape cuttings from the machine. Clean the typefaces with a stiff brush, paying particular attention to those with small closed loops, eg A, %, P.

3. Check the carriage return tape for fraying and renew as necessary.

4. Inspect the ink ribbon for wear and renew if necessary.

5. Carry out the lubrication instructions. After lubrication, use a dry cloth to remove any lubricant that may have spread from the points of application. In particular, ensure that the transmitter contact assembly, platen, platen pressure rollers, ribbon guides and reperforator tape guides are free from all traces of lubricant.

6. Check all drive shaft bearings for end-play and side-play, paying particular attention to the adjustments listed below.
   (*a*) Selector drive shaft end-play—Adjustment No. 7
   (*b*) Selector rockshaft end-play—Adjustment No. 2
   (*c*) Typehead carriage end-play—Adjustment No. 3

Motor and Governor

7. Remove the motor from the machine main base as described in the dismantling instructions. Take off the cover over the commutator end of the motor, the governor cover and the governor contact assembly cover.

8. Examine the length of the brushes as seen through the slot in the side faces of the brush boxes, and note whether any coils of the brush springs can be seen. If so, fit a new brush and spring assembly.

9. Rotate the armature shaft slowly by hand and check for tight spots or excessive end-play.

10. Using a dry cloth and a stiff brush, remove all carbon dust which may have accumulated inside the motor body, on the end castings, the armature windings or the commutator slots. Examine the surface of the commutator for wear or pitting and, if necessary, reface it. If there is a smooth black glaze on the commutator surface, however, do not attempt to remove it in any way.

11. Using a soft brush, remove all carbon dust which may have accumulated in the governor contact assembly, particularly between the contact blades. Examine the governor contacts for pitting and burnish or renew as necessary. Inspect the nylon contact peg for wear. If the peg is worn, remove the governor contact assembly from the sub-base of the motor unit and fit a new peg. Refit the governor contact assembly to the sub-base and hold the assembly against its abutment before tightening the fixing screw.

12. Refit the commutator cover, the governor cover and the governor contact assembly cover. Refit the motor to the machine main base and re-connect the signal and powerplugs. Switch on the motor and check its speed.

Select and Translator Units

13. Check the following adjustments and correct where necessary.
   (*a*) Translator clutch—Adjustment No. 4
   (*b*) Pin-box traverse multiplying lever—Adjustment No. 5
   (*c*) Pecker retention arm—Adjustment No. 6
   (*d*) Selector detent clearance—Adjustment No. 7
   (*e*) Selector camshaft retention lever—Adjustment No. 8
   (*f*) Selector clutch—Adjustment No. 9
   (*g*) Translator trip operating lever stop—Adjustment No. 10
   (*h*) Translator clutch trip—Adjustment No. 11
   (*j*) Starter trip from electromagnet—Adjustment No. 12
   (*k*) Starter trip from translator clutch—Adjustment No. 13
   (*l*) Pecker/code selection pin clearance—Adjustment No. 14
   (*m*) Pecker traverse—Adjustment No. 15

Carriage Return, Dashpot, Line and Letter Feed Mechanism

14. Check the operation of the dashpot and the carriage return spring drum. Check the vertical carriage return and line feed levers for positive action from their function bars.

15. Check the following adjustments and correct where necessary.
   (*a*) Carriage return pawl lift—Adjustment No. 16
   (*b*) Line feed lever stop plate—Adjustment No. 17
   (*c*) Line feed pawl overthrow stops—Adjustment No. 18
   (*d*) Typehead carriage stop screw and pawl latch—Adjustment No. 19
   (*e*) Feed and retention pawl height—Adjustment No. 20
   (*f*) Typehead carriage feed link—Adjustment No. 21
   (*g*) Carriage return spring—Adjustment No. 22
   (*h*) Dashpot—Adjustment No. 23

Printing Mechanism

16. Inspect the typefaces for wear and check the type alignment. Check the surfaces of the platen and the platen pressure rollers for wear and renew as necessary.

17. Check the operation of the ink ribbon control mechanism, and the action of the ribbon changeover mechanism at each end of the ribbon traverse.

18. Check the following adjustments and correct where necessary.

(*a*) Friction feed platen—Adjustment No. 24
(*b*) Sprocket feed platen—Adjustment No. 25
(*c*) Paper guide retainers—Adjustment No. 26
(*d*) Platen retention pawl—Adjustment No. 27
(*e*) Print spring—Adjustment No. 28
(*f*) Typehead/platen clearance—Adjustment No. 29
(*g*) Print beam stop screw—Adjustment No. 30
(*h*) Typehead corrector—Adjustment No. 31
(*j*) Typehead corrector track rail—Adjustment No. 32
(*k*) Ribbon unit pawls—Adjustment No. 33
(*l*) Ribbon jumper arm—Adjustment No. 34
(*m*) Typehead height-final setting—Adjustment No. 35

Keyboard and Transmitter

19. Inspect the transmitter code, sequential and send-receive contacts and burnish as necessary.

20. Check the operation of the run out keybar for positive action.

21. Check the following adjustments and correct where necessary.

(*a*) Contact springs—Adjustment No. 36
(*b*) Keyboard combination bar reset—Adjustment No. 37
(*c*) Selector bar/selection pin alignment—Adjustment No. 38
(*d*) Selector bar/selection pin clearance—Adjustment No. 39
(*e*) Lag weight release lever stop—Adjustment No. 40
(*f*) Lag weight trip—Adjustment No. 41
(*g*) Lag weight movement—Adjustment No. 42
(*h*) Translator trip from lag weight—Adjustment No. 43
(*j*) Send-receive delay lever clearance—Adjustment No. 44
(*k*) Send-receive switch contacts—Adjustment No. 45
(*l*) Send-receive contact delay—Adjustment No. 46
(*m*) Lag weight transit timing—Adjustment No. 47

ADJUSTMENT INSTRUCTIONS

1. Selector Drive Shaft End-play

Check

1.1 Check that the selector drive shaft, **Fig 2.70**, is free to turn and that its end-play does not exceed 3mil.

Action

1.2 To adjust, remove the outer nut and its washer, slacken the locknut and turn the special square nut located in the collar until the correct end-play is present. Clamp the square nut with its locknut and refit the outer nut and its washer.

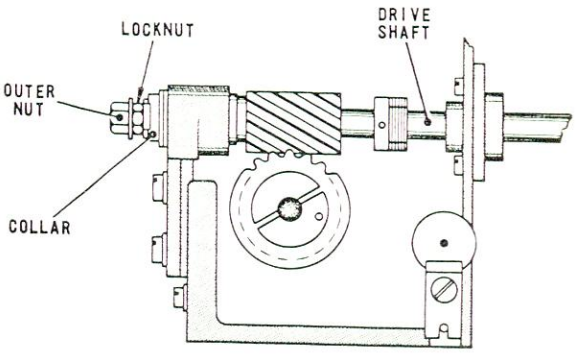


Fig 2.70. Selector drive shaft.

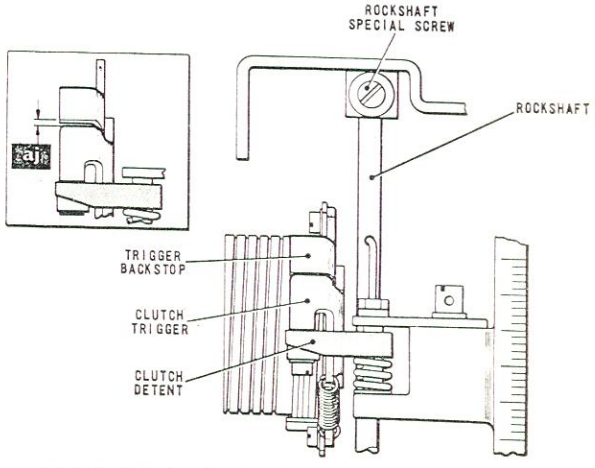
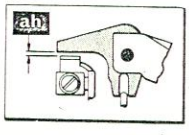


Fig 2.71. Selector clutch trigger mechanism—plan view.



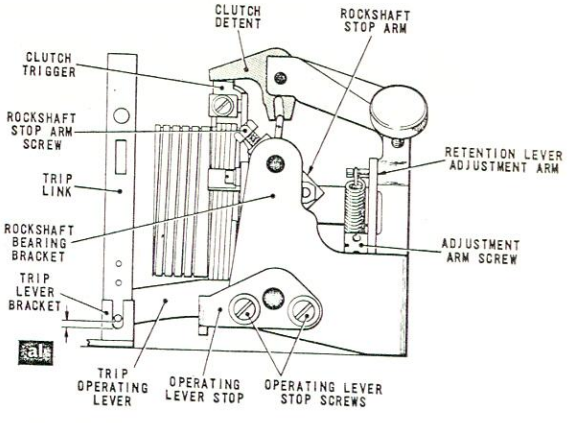


Fig 2.72. Selector clutch trigger mechanism—side view.

2. Selector Rockshaft End-play

Check

2.1 Check that there is a maximum of 3mil end-play in the rockshaft, **Fig 2.71,** and, with the electromagnet armature in the mark position, check that the pin on the rockshaft stop arm, **Fig 2.72**, is touching the edge of the rockshaft bearing bracket.

Action

2.2 To adjust, slacken the screw securing the rockshaft stop arm until it is friction tight and position the stop arm so that the correct end-play is present. Then, ensuring that the electromagnet armature remains at mark and that the end-play which has just been set is not disturbed, turn the stop arm about the rockshaft until the pin just touches the rockshaft bearing bracket. Tighten the stop arm screw.

3. Typehead Carriage End-play

Check

3.1 Check that there is not more than 5mil end-play on the typehead carriage.

Action

3.2 If the end-play is excessive, remove the two screws securing the typehead carriage left-hand bearing block, **Fig 2.73**. Hold the carriage so that the gears and racks remain in mesh and lift off the bearing block. Add 5mil shims as necessary between the bearing block and the carriage until the end-play is less than 5mil. Refit the bearing block and tighten its securing screws.

The bearing block must *always* be clamped in its extreme left-hand position.

4. Translator Clutch

Check

4.1 With the translator camshaft in the rest position and the retention lever roller located in its recess in the retention cam, lift the translator clutch abutment so that the clutch trigger, **Fig 2.74**, is released. Turn the machine by hand until the clearance between the trigger and its backstop can be measured easily and check that this clearance is now 93–110mil (dimension "ad").

Action

4.2 To adjust, turn the machine by hand until the clutch adjustment plate is accessible, slacken the two screws securing the adjustment plate and move the plate until dimension "ad" is achieved. Tighten the screws.

5 Pin-box Traverse Multiplying Lever

Check

5.1 Clamp the pivot of the traverse multiplying lever, **Fig 2.75**, in the mid-position of its movement.

5.2 Set the machine up so that it is at rest with the translator unit pin-box in its forward position, ie nearest the front of the machine. Lift the translator clutch abutment and turn the machine by hand until the function bars have just moved towards the rear of the machine.

5.3 Lightly pull the traverse multiplying lever outwards so that any backlash in the mechanism is taken up. Check that there is now a clearance (dimension "ae"—inset) between the front end of the slot in the lever and the shouldered pin.

5.4 Return the machine to the rest position. Lift the translator clutch abutment and turn the machine by hand until the function bars have again just moved towards the rear of the machine.

5.5 Lightly push the traverse multiplying lever inwards so that any backlash in the mechanism is taken up. Check that a clearance equal to dimension "ae" now exists between the rear end of the slot in the lever and the shouldered pin.

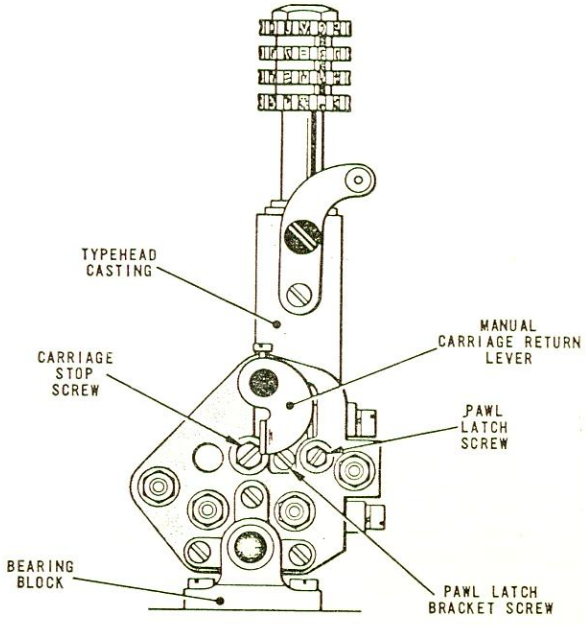


Fig 2.73. Typehead carriage—left-hand end.

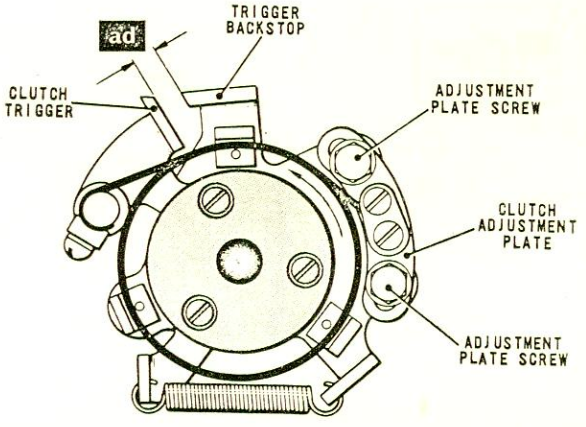


Fig 2.74. Translator clutch—rear view.

Action

5.6 To adjust, remove the operation counter, slacken the nut securing the shouldered pin and reposition the pin until both the above conditions are satisfied. Tighten the pin securing nut and refit the operation counter.

6. Pecker Retention Arm

(a) Horizontal Position

Check

6.1 Move the electromagnet armature to the space position so that the selector clutch detent, **Fig 2.72**, is released. Turn the machine by hand until the striker lever, **Fig 2.76,** is on one of the high points of the striker cam. Check that there is now a horizontal clearance of 5–10mil (dimension "af") between the hook on the retention arm and the engagement face of the striker lever.

Action

6.2 If this is not so, slacken the screws securing the retention arm bracket until it is friction tight. Using the screwdriver slot in the top of the bracket, lever the retention arm sideways until the correct clearance is present. Tighten the bracket screws.

(b) Vertical Position

6.3 Move the electromagnet armature to the mark position and continue to turn the machine by hand until the striker lever locates in one of the recesses in the striker cam. Check that this movement causes the lever to pass over the retention arm with an estimated vertical clearance of 10–20mil (dimension "ag"—inset).

Action

6.4 To adjust, ensure that the electromagnet armature is still in the mark position, slacken the mounting bracket screw and turn the adjustment screw until the correct vertical clearance is obtained. Tighten the mounting bracket screw.

7. Selector Detent Clearance

Check

7.1 With the machine in the rest position and the selector clutch trigger, **Fig 2.72,** held against the clutch detent, move the electromagnet armature to the space position so that the detent is released. Maintaining light pressure on the detent to take up any backlash present, check that there is now a vertical clearance of 5–10mil (dimension "ah"—inset) between the clutch trigger and the detent.

Action

7.2 To adjust, slacken the rockshaft special screw, Fig **2.71**, and, ensuring that the electromagnet armature remains at space, reposition the detent until dimension "ah" is satisfied. Tighten the rockshaft screw.

8. Selector Camshaft Retention Lever

Check

8.1 With the electromagnet armature in the mark position, the retention lever roller located in its recess in the retention cam and the clutch trigger, **Fig 2.71,** held against the clutch detent, check that there is a clearance of 10–15mil (dimension "aj"—inset) between the trigger and its backstop,

Action

8.2 If this is not so, slacken the capstan-headed screw securing the retention lever adjustment arm, **Fig 2.72**, and push the arm inwards so that the cam assembly moves clockwise and the trigger backstop, **Fig 2.71,** presses the trigger against the detent. Now gently move the cam assembly counter-clockwise until dimension "aj" is set up and then tighten the adjustment arm screw, **Fig 2.72.**

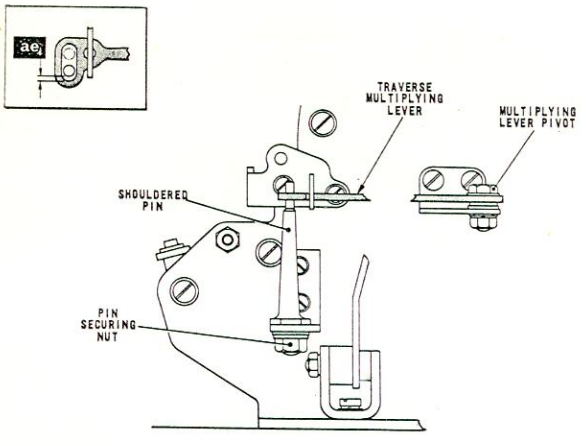


Fig 2.75. Pin-box traverse action.

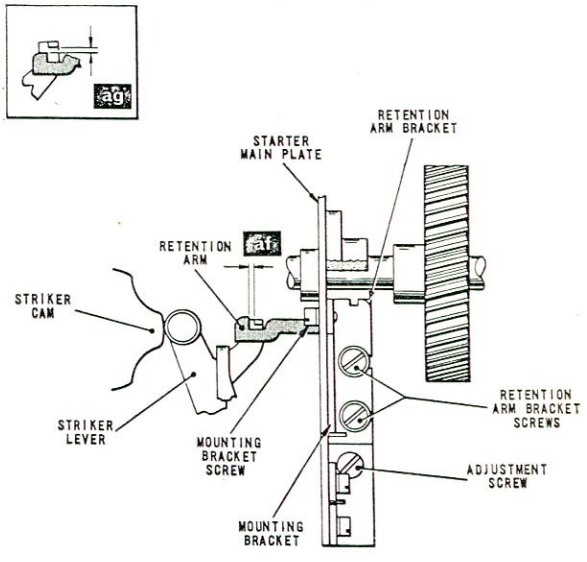


Fig 2.76. Pecker retention arm mechanism—rear view.

9. Selector Clutch

Check

9.1 Move the electromagnet armature to the space position so that the clutch detent is lifted and the clutch trigger, **Fig 2.77,** is released. Check that there is now a clearance of 93–110mil (dimension "ak") between the clutch trigger and its backstop.

9.2 To adjust, turn the machine by hand until the clutch adjustment plate is accessible, slacken the two screws securing the adjustment plate and move the plate until dimension "ak" is achieved. Tighten the adjustment plate screws.

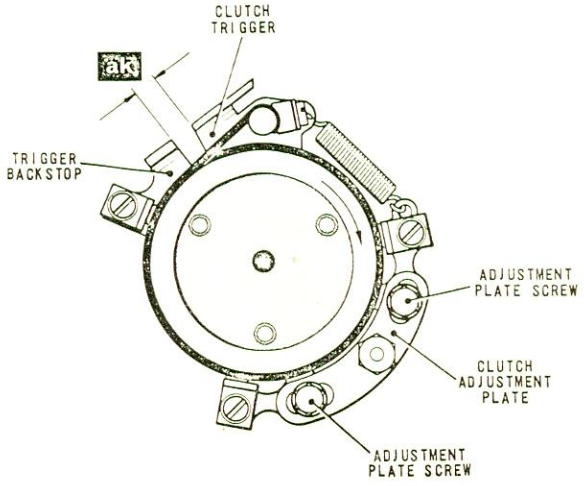


Fig 2.77. Selector clutch.

10. Translator Trip Operating Lever Stop

Check

10.1 With the machine at rest, check that the trip operating lever, **Fig 2.72**, is against its stop and that there is a clearance of 3–10mil (dimension "al") between the pin on the trip link and the bottom of the slot in the trip lever bracket.

Action

10.2 To adjust, slacken the two screws securing the trip operating lever stop until friction tight and lever up the stop as far as it will go. Pull the trip link forward against its guides and press down so that the pin on the link is at the bottom of the slot in the bracket. Maintaining this condition, measure the clearance between the operating lever stop and the surface of the translator unit base plate with a feeler gauge.

10.3 Add a further 3mil to the operating lever stop/base plate clearance determined above and re-insert the gauge between the stop and the base plate. With this increased dimension set up, tighten the top screws. Repeat Check 10.1 which should now be satisfied.

11. Translator Clutch Trip

Check

11.1 Lift the trip operating lever, **Fig 2.72**, so that the trip link passes over the abutment frame trip lever, **Fig 2.78**. Holding the operating lever, **Fig 2.72,** in this position, insert a 15mil feeler gauge between the operating lever and the hook of the operating lever stop. Release the lever so that it moves down on to the gauge and check that the translator clutch abutment does not trip.

11.2 Replace the 15mil feeler gauge with a 5mil gauge and repeat Check 11.1. Check that the translator clutch abutment will now trip.

Action

11.3 To adjust, maintain the condition set up in Check 11.2 and slacken the capstan-headed screw securing the adjustment plate, **Fig 2.78**. Holding the slide block in contact with the abutment frame trip lever, move the adjustment plate until the clutch abutment trips the clutch trigger. Tighten the adjustment plate screw.

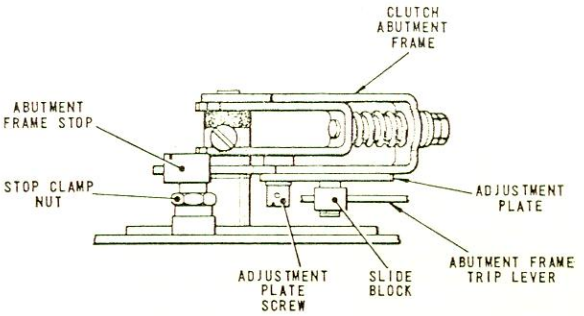


Fig 2.78. Translator clutch abutment mechanism.

12. Starter Trip from Electromagnet

Check

12.1 Disengage the starter arm pin, **Fig 2.79,** from the worm wheel. Depress the starter arm as far as it will go

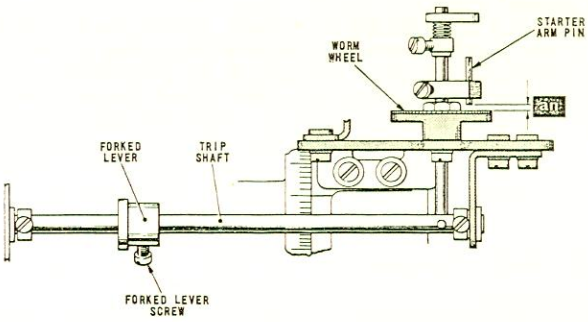


Fig 2.79. Starter trip shaft linkage.

so that the starting lever, **Fig 2.80**, moves fully down. Holding the arm in this position, and with the electromagnet armature against the marking stop, check that there is a maximum clearance of 6mil (dimension "am") between the rockshaft peg and the starter operating link.

12.2 Move the electromagnet to space and check that this action causes the peg to displace the link.

Action

12.3 To adjust, slacken the two screws securing the starter lever stop bracket and, with the electromagnet armature in the mark position, move the stop bracket by means of its screwdriver slot until both conditions are satisfied. Tighten the bracket screws.

13. Starter Trip from Translator Clutch

Check

13.1 Trip the translator clutch by raising and then lowering the trip operating lever, **Fig 2.72**. Holding the trip operating lever fully down, check that there is now a clearance of 5–10mil (dimension "an") between the starter arm pin, **Fig 2.79**, and the worm wheel.

Action

13.2 To adjust, slacken the screw clamping the forked lever and turn the trip shaft until the correct clearance is obtained. Tighten the clamp screw.

14. Pecker/Code Selection Pin Clearance

Check

14.1 Move the electromagnet armature to the mark position and check that the selector shaft is held at rest. Lift the translator clutch abutment and turn the machine through two complete cycles. Check that all the selection pins in the pin-box have been withdrawn.

14.2 Move the electromagnet armature to space. Turn the machine by hand until the pecker, **Fig 2.81**, is opposite the first (inner) selection pin and the striker lever, **Fig 2.76**, is held away from the striker cam by the retention arm hook.

14.3 Lightly press the pecker, **Fig 2.81**, towards the selection pin to take up any play that may be present and check that there is a clearance of 30–45mil (dimension "ap") between the pecker and the pin.

14.4 Repeat this procedure with the pecker opposite the fifth (outer) selection pin.

Action

14.5 If adjustment is necessary, remove the keyboard and stand the machine on its back. Disconnect the pecker frame return spring and slacken the nuts securing the pecker frame until friction tight. Ensure that the striker lever, **Fig 2.76**, is held by the retention arm hook and reposition the pecker frame, **Fig 2.81**, on its shaft until the correct clearance is present at both ends of the pecker traverse. Tighten the frame securing nuts, re-connect the pecker frame return spring and refit the keyboard.

15. Pecker Traverse

Check

15.1 Lift the selector clutch detent and then move the electromagnet armature to the mark position. Turn the machine slowly by hand and check that each selection pin, **Fig 2.81**, is struck by the pecker and that the area of contact between the pecker and the pins is as great as possible over the complete traverse. Repeat this check with the pin-box in its alternative position.

Action

15.2 To adjust, remove the operation counter, slacken the screw securing the traverse pivot bracket, **Fig 2.82**,

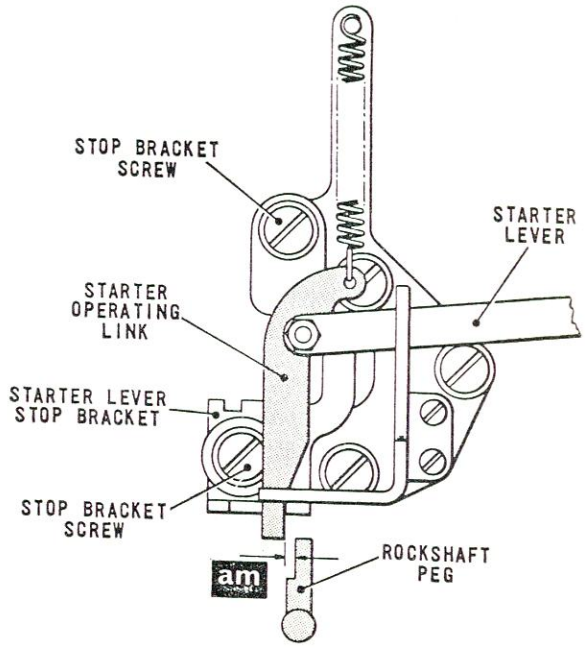


Fig 2.80. Starter trip from electromagnet.

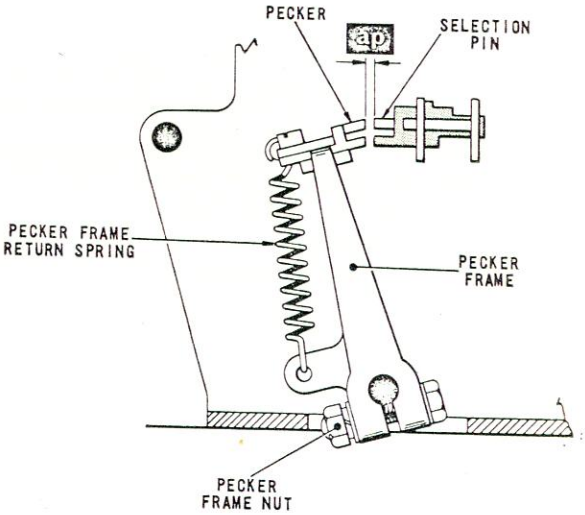


Fig 2.81. Pecker/selection pin clearance.

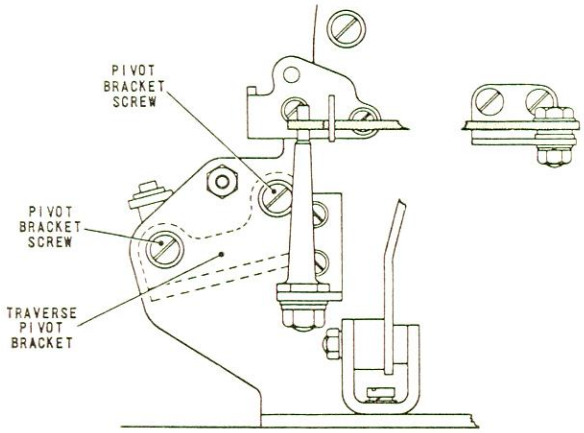


Fig 2.82. Pecker/selection pin engagement.

and reposition the bracket until the above conditions are satisfied for both sets of pins. Tighten the bracket screws and refit the operation counter.

16. Carriage Return Pawl Lift

Check

16.1 Operate the carriage return manual lever to move the typehead carriage to its extreme left-hand position. Set up the carriage return code combination (SSSMS) on the pins, lift the translator clutch abutment and turn the machine by hand until the noses of the feed and retention pawls, **Fig 2.83**, are at their highest point. Check that the pawls are now high enough to enable the pawl latch to

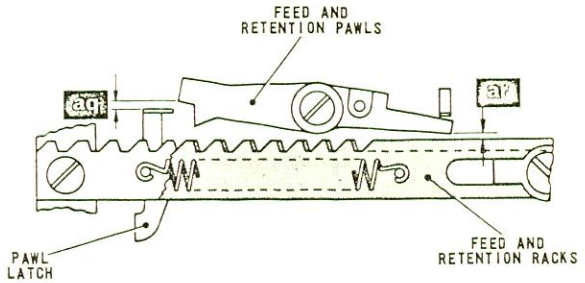


Fig 2.83. Feed and retention rack clearances.

pass beneath their noses with a clearance of approximately 30mil (dimension "ag"). Check also that there is a clearance of approximately 30mil (dimension "ar") between the tails of the pawls and the top of the rack teeth.

Action

16.2 To adjust, stand the machine on its back, slacken the screw clamping the carriage return operating arm, **Fig 2.84**, and reposition the arm until both the above clearances are obtained. Tighten the clamp screw.

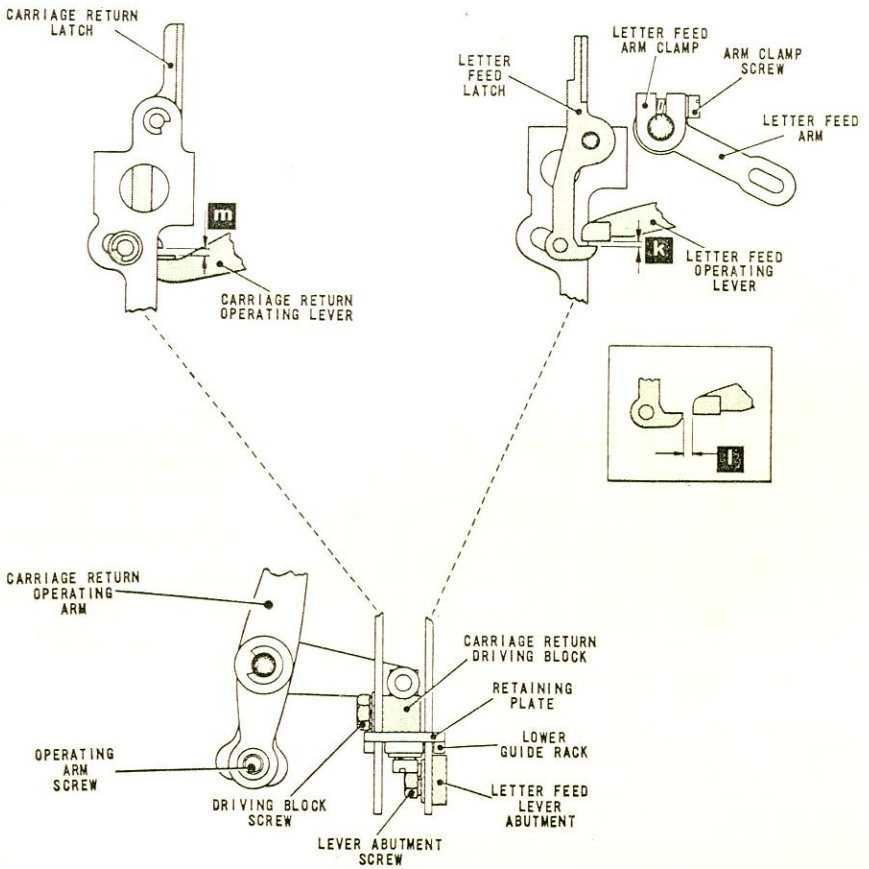


Fig 2.84. Letter feed and carriage return control linkages.

17. Line Feed Lever Stop Plate

Check

17.1 Move the feed change lever, **Fig 2.85,** to the double feed position, ie towards the front of the machine.

17.2 With the machine in the rest condition, turn the platen by hand and check that there is a radial clearance of 5–50mil (dimension "as") between the line feed pawl and its ratchet wheel.

17.3 Move the line feed latch, **Fig 2.86,** into the path of the line feed operating lever and pull the line feed roller outwards so that the lever is arrested by the latch hook, as shown in the figure. With this condition set up, check that there is a minimum clearance of 8mil (dimension "at") between the roller and the line feed cam.

17.4 Move the feed change lever, **Fig 2.85,** to the single feed position and repeat Checks 17.2 and 17.3.

Action

17.5 To adjust, slacken the screws securing the line feed lever stop plate and re-position the plate until all the above conditions are obtained. Tighten the stop plate screws.

18. Line Feed Pawl Overthrow Stops

Check

18.1 Move the feed change lever, **Fig 2.85,** to the double feed position. Depress the line feed key or, if the machine has no keyboard, set up the line feed code combination (SMSSS) on the pins. Lift the translator clutch abutment and turn the machine by hand until the line feed mechanism is fully fed.

18.2 Without applying excessive force, attempt to turn the platen by hand in the normal direction of rotation. Check that some movement is possible but that it does not exceed 15mil measured at the edge of the platen.

Action

18.3 If this is not so, slacken the eccentric stop securing nut, **Fig 2.87,** and turn the eccentric stop, **Fig 2.85,** until the correct amount of overthrow is present. Tighten the nut.

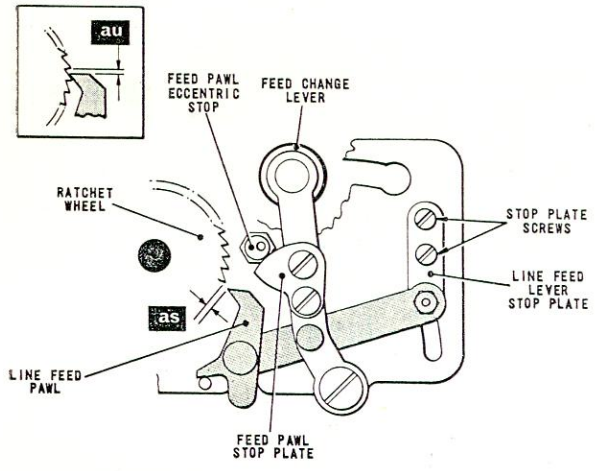


Fig 2.85. Line feed ratchet wheel mechanism.

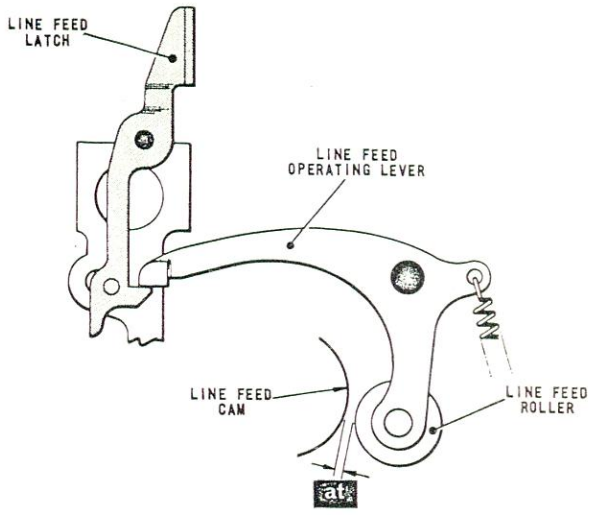


Fig 2.86. Line feed operating lever.

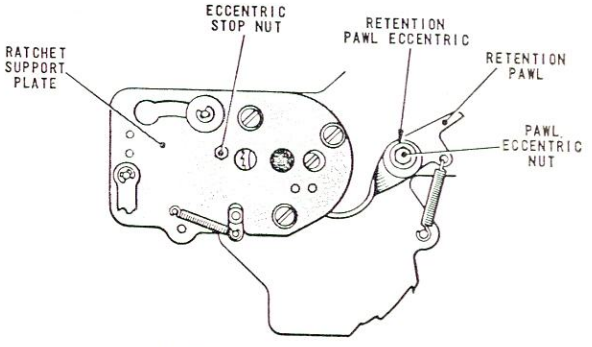


Fig 2.87. Ratchet support plate.

Check

18.4 Move the feed change lever to the single feed position and check that the same amount of overthrow is present as with the double feed setting.

Action

18.5 To adjust, slacken the screws clamping the feed pawl stop plate and reposition the plate until the overthrow is correct. Tighten the plate screws.

19. Typehead Carriage Stop Screw and Pawl Latch

Check

19.1 Operate the carriage return manual lever, **Fig 2.73,** so that the typehead moves to its extreme left-hand position. Check that the retention pawl, **Fig 2.88,** is now resting in the correct tooth of the retention rack for the required left-hand margin, ie

Retention rack tooth	Nominal left-hand margin
6th	0·5in
7th	0·6in
8th	0·7in
9th	0·8in

19.2 Check that the retention pawl is clear of the next tooth of the retention rack by approximately 5mil (dimension "av") and that the pawl latch clears the feed and retention pawls by approximately 15mil (dimension "aw")

Action

19.3 If these conditions are not satisfied, adjust as follows:

(*a*) Slacken the locknut of the pawl latch screw, **Fig 2.73**, and turn the screw until its end is well clear of the pawl latch, **Fig 2.88**.

(*b*) Slacken the locknut of the carriage stop screw, **Fig 2.73**, and turn the screw until the retention pawl, **Fig 2.88**, engages the correct tooth of the retention rack and until dimension "av" is set up. Clamp the carriage stop screw, **Fig 2.73**, in this position with its locknut.

(*c*) Turn the pawl latch screw until dimension "aw" is obtained and clamp the screw in this position with its locknut.

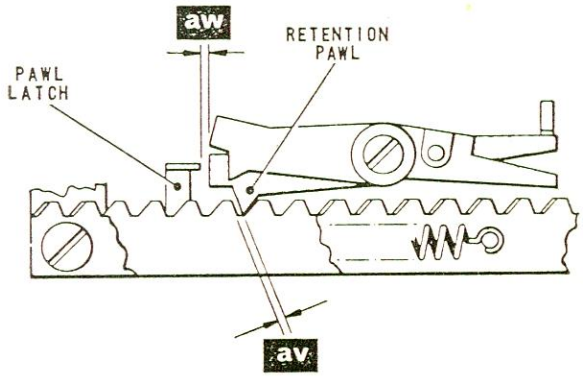


Fig 2.88. Typehead retention pawl.

20. Feed and Retention Pawl Height

Check

20.1 Slide the typehead to the right-hand limit of its travel. Holding the typehead in this position, operate the carriage return manual lever, **Fig 2.73,** so that the feed and retention pawls, **Fig 2.89**, are held up by the pawl latch. Allow the typehead to slide slowly to the left and check that the tails of both pawls clear the racks by 30–45mil.

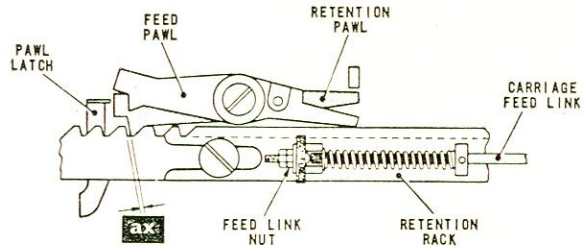


Fig 2.89. Typehead carriage feed link.

Action

20.2 If this is not so, slacken the two screws (one only shown in **Fig 2.73**) clamping the pawl latch bracket to the typehead casting, and reposition the bracket until the correct pawl clearance is present. Tighten the bracket clamp screws.

21. Typehead Carriage Feed Link

Check

21.1 Operate the carriage return manual lever, **Fig 2.73**, so that the typehead moves to its extreme left-hand position. Depress any printing key or, if the machine has no keyboard, set up any printing combination on the pins. Lift the translator clutch abutment and turn the machine by hand until the carriage feed link, **Fig 2.89**, has moved to its extreme right-hand position.

21.2 Move the pawl latch away from the pawls. Check that the retention pawl has dropped into engagement with the retention rack and is clear of the next tooth face by an estimated 4–8mil (dimension "ax").

The feed pawl is shown lifted in the figure to clarify the required retention pawl condition.

Action

21.3 To adjust, carry out the following procedure:

(*a*) Set up the machine as in Check 21.1, ie with the letter feed mechanism fully fed.

(*b*) Unscrew the carriage feed link nut and its locknut so that the feed rack is allowed to move to its extreme left-hand position under the action of its spring.

(*c*) Slowly tighten the carriage feed link nut until the retention pawl just drops into the retention rack, then turn a further quarter of a turn to achieve dimension "ax". Clamp the nut in this position with its locknut.

22. Carriage Return Spring

Check

22.1 Slide the typehead to its extreme right-hand posi-

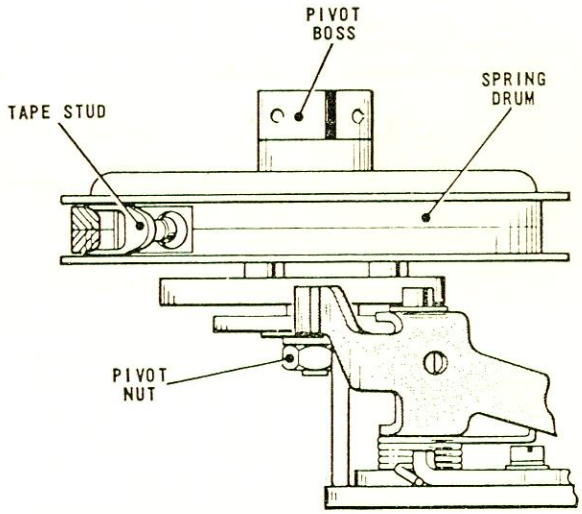


Fig 2.90. Carriage return spring drum.

tion. Apply a tension gauge to the spring drum tape stud, **Fig 2.90**, and check that there is a force of 4½–5lb (2·04–2·27kg) acting at the periphery of the drum.

Action

22.2 If this is not so, insert a tommy pin into one of the holes in the capstan-headed pivot boss and slacken the pivot nut. Turn the pivot boss approximately a quarter of a turn at a time, clockwise to decrease or counter-clockwise to increase the tension, and tighten the pivot nut. Repeat this procedure as often as necessary until the correct tension is achieved.

23. Dashpot

Check

23.1 Operate the carriage return manual lever, **Fig 2.73**, so that the typehead moves to its extreme left-hand position. Stand the machine on its back and check that it is now possible to move the dashpot piston, **Fig 2.91**, a further 60mil into its cylinder.

Action

23.2 If this is not so, slacken the three dashpot securing screws. Move the dashpot unit until the above condition is satisfied and tighten the securing screws.

Check

23.3 Slide the typehead to its extreme right-hand position. Operate the carriage return manual lever and check that the typehead returns to the left-hand position with the minimum of impact.

Action

23.4 To adjust, carry out the following procedure:

(*a*) Slacken the locknut of the dashpot air vent screw and turn the screw clockwise until the air vent is fully closed. This will cause pneumatic bounce to occur when the typehead is returned to its left-hand position.

(*b*) Turn the air vent screw counter-clockwise a quarter of a turn at a time and repeat Check 23.3. Repeat this procedure as often as necessary until the typehead bounce *just* ceases, and lock the air vent screw in this position with the locknut.

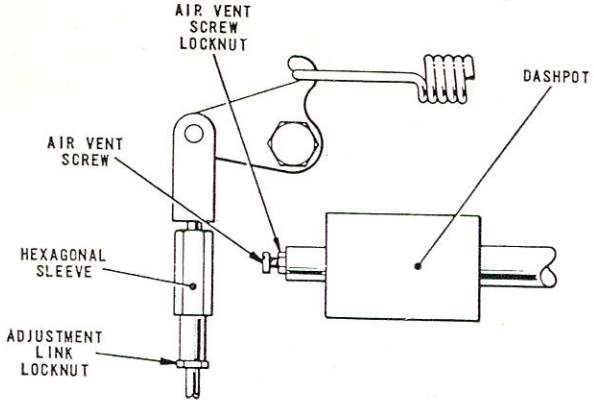


Fig 2.91. Dashpot/print spring mechanism.

24. Friction Feed Platen

Check

24.1 Move the feed change lever, **Fig 2.85**, to the double feed position. Depress the line feed key or, if the machine has no keyboard, set up the line feed code combination (SMSSS) on the pins. Lift the translator clutch abutment and turn the machine by hand until the line feed mechanism is fully fed. Check that the feed pawl is now clear of its eccentric stop. Check also that there is a maximum clearance of 15mil (dimension "au"—inset) between the feed pawl and the next tooth of the ratchet wheel.

Action

24.2 To adjust, slacken the nut securing the retention lever, **Fig 2.92**, and turn the eccentric pivot by means of its screwdriver slot until dimension "au" is satisfied. Tighten the nut.

If the movement available on the pivot is insufficient to satisfy Check 24.1, slacken the two ratchet wheel clamp screws, move the ratchet wheel slightly with respect to the platen and tighten the clamp screws. Access to the clamp screws is via the hole in the ratchet support plate, **Fig 2.87**.

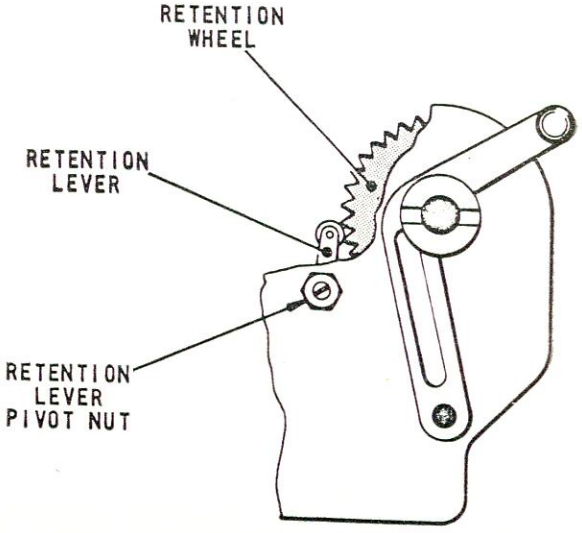


Fig 2.92. Friction speed platen—left-hand end.

25. Sprocket Feed Platen

Check

25.1 Operate the sprocket feed change lever so that the feed pins protrude, and insert a sheet (or sheets) of stationery into the machine. Ensure that the pins are correctly located in the holes in the paper and check that the printing point is correctly positioned with respect to any "boxes" on the stationery.

Action

25.2 If it is not, slacken the three screws securing the retention wheel, **Fig 2.93**, until they are friction tight and, holding the platen so that the correct paper/type alignment is present, move the retention wheel until its roller is fully engaged. Tighten the three retention wheel screws.

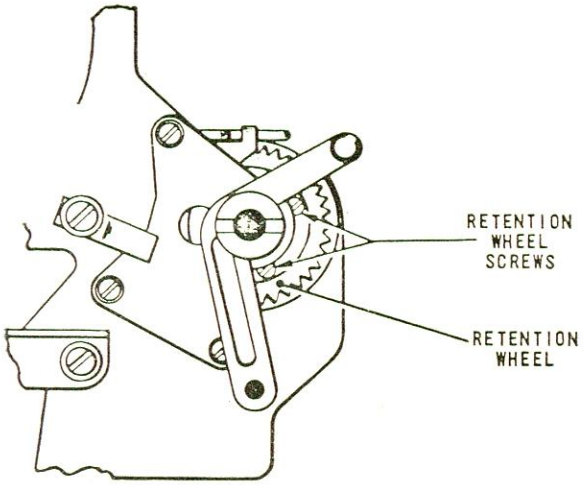


Fig 2.93. Sprocket feed platen—left-hand end.

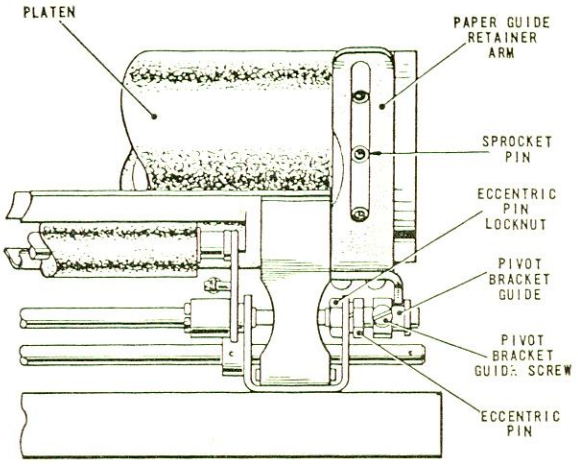


Fig. 2.94. Paper guide retainer.

Check

25.3 Depress the line feed key or, if the machine has no keyboard, set up the line feed code combination (SMSSS) on the pins. Lift the translator clutch abutment and turn the machine by hand until the line feed mechanism is fully fed. Ensure that the retention lever roller is fully engaged in the retention wheel. Check that the feed pawl, **Fig 2.85**, is now clear of its eccentric stop and there is a maximum clearance of 15mil (dimension "au"—inset) between the feed pawl and the next tooth of the ratchet wheel.

Action

25.4 To adjust, remove the three ratchet wheel clamp screws, turn the wheel so that the next set of holes coincides with those of the clamp screws and tighten the screws. Access to the clamp screws is via the hole in the ratchet support plate.

25.5 Repeat Check 25.3 and, if necessary, Adjustment 25.4 until the correct platen/ratchet relationship is achieved.

Check

25.6 With the right-hand paper guide retainer arm, **Fig 2.94**, located in the groove in its pivot bracket guide, check that the slot in the retainer arm is positioned symmetrically about the right-hand sprocket pins. Repeat this check with the left-hand guide retainer arm.

Action

25.7 To adjust, slacken the screw securing the pivot bracket guide and move the guide along its eccentric pin until the condition is satisfied. Tighten the guide screw.

26. Paper Guide Retainers

Check

26.1 Turn the platen by hand and check that the clearance between the paper guide retainer arms, **Fig 2.94**, and the platen is sufficient to allow the required thickness of paper to pass smoothly.

Action

26.2 To adjust, slacken the locknut securing the eccentric pin and rotate the pin until the condition is satisfied. Tighten the locknut.

27. Platen Retention Pawl

Check

27.1 With the machine in the rest position, check that the retention pawl, **Fig 2.87**, is engaged in the ratchet wheel and that it is possible to turn the platen against the normal direction of rotation by a maximum of 15mil measured at the edge of the platen.

Action

27.2 To adjust, slacken the nut securing the retention pawl eccentric and turn the eccentric until the correct engagement is achieved. Tighten the nut.

28. Print Spring

Check

28.1 Ensure that the top end of the print spring change lever is towards the rear of the machine. Stand the machine on its back and check that a force of approximately 3lb (1·36kg), applied to the print beam, **Fig 2.95**, at and in the direction of the arrow, just moves the beam.

Action

28.2 To adjust, slacken the locknut of the spring adjustment link, **Fig 2.91**, and turn the hexagonal sleeve until the correct tension is present. Tighten the locknut.

29. Typehead/Platen Clearance

Check

29.1 Depress the letter "X" key or, if the machine has no keyboard, set up the letter "X" combination (MSMMM)

on the pins. Lift the translator clutch abutment and turn the machine by hand until the print lever, **Fig 2.96**, is on the highest point of its cam (just prior to fall off). Using a slip gauge check that there is a clearance of approximately 0·5 in (dimension "ay") between the typehead, **Fig 2.97**, and the platen.

Action

29.2 To adjust, continue to turn the machine by hand until the typehead moves forward to print. Stand the machine on its back, withdraw the screw securing the pin retainer, **Fig 2.95**, and remove the retainer from the print shackle. Disconnect the print beam from the print shackle and slacken the shackle locknut. Turn the shackle clockwise to increase or counter-clockwise to decrease the dimension. Re-connect the print beam to the shackle, refit the pin retainer and tighten the retainer screw.

29.3 Repeat Check 29.1 and, if necessary, Adjustment 29.2 until the correct dimension is set up. Tighten the shackle locknut.

30. Print Beam Stop Screw

Check

30.1 Depress the letter "X" key or, if the machine has no keyboard, set up the letter "X" combination (MSMMM) on the pins. Lift the translator clutch abutment and turn the machine by hand until the typehead moves forward to print. Using a slip gauge, check that there is a clearance of 160–220mil between the typehead and the platen.

Action

30.2 If this is not so, stand the machine on its back and disconnect the print spring. Add or remove 5mil shims as necessary under the print beam stop screw until the correct clearance is obtained. Re-connect the print spring.

31. Typehead Corrector

Check

31.1 Slide the typehead to the middle of the line. Depress the letter "X" key or, if the machine has no keyboard, set up the letter "X" combination (MSMMM) on the pins. Lift the translator clutch abutment and turn the machine by hand until the typehead moves forward to print. Check that the typehead backlash is equal in both directions by carrying out the following procedure:

(*a*) Press the typehead casting towards the platen so that the letter is printed. Turn the platen knob until the paper has moved up one line.

(*b*) Pull the typehead back so that the corrector lever, **Fig 2.98**, is out of engagement and, turning the typehead slightly to the left to take up the backlash, press the typehead casting towards the platen so that the letter is printed again on the lower line.

(*c*) Repeat Check 31.1(*b*), this time turning the typehead to the right.

(*d*) Check that the image printed appears as shown in the inset to **Fig 2.98**. This inset shows the image obtained when the backlash is equal in both directions.

Action

31.2 To adjust, slacken the nut securing the front splined shaft, **Fig 2.99**, and turn the typehead clockwise

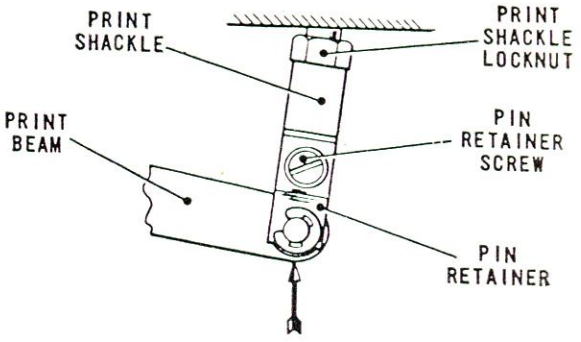


Fig 2.95. Print beam/print shackle linkage.

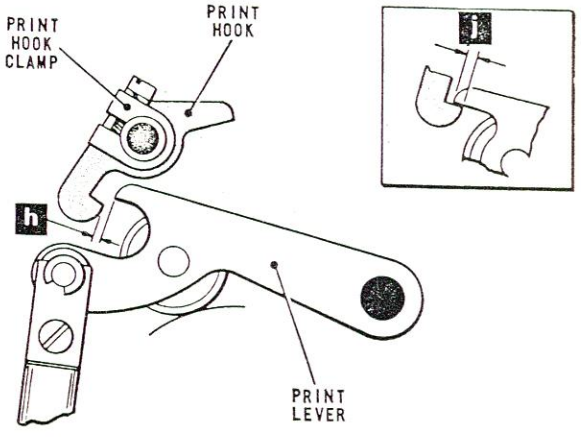


Fig 2.96. Non-print hook mechanism.

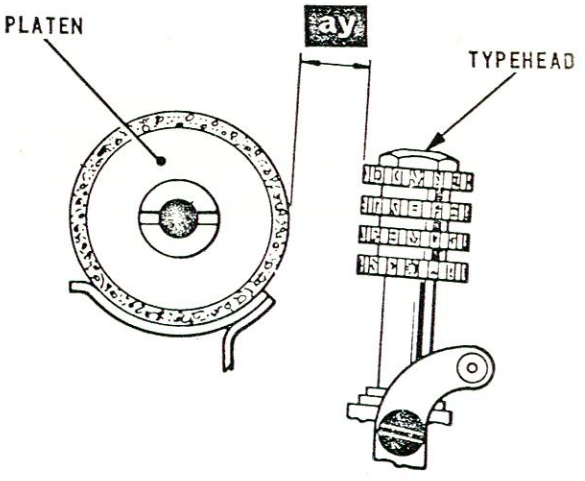


Fig 2.97. Typehead/platen clearance.

or counter-clockwise until the backlash is equal in both directions. When this condition is satisfied, insert a tommy pin into the hole in the front splined shaft and, holding the shaft with the pin, tighten its securing nut.

Check

31.3 Press the typehead casting towards the platen again and check that the letter "X" thus printed is equal in density on both sides of the character.

Differences in density between the upper and lower legs should be ignored at this stage.

Action

31.4 If this is not so, slacken the screw securing the eccentric pivot of the corrector lever, **Fig 2.98**, and turn the pivot until the letter "X" is correctly positioned. Holding the pivot in this position with a spanner, tighten its securing screw.

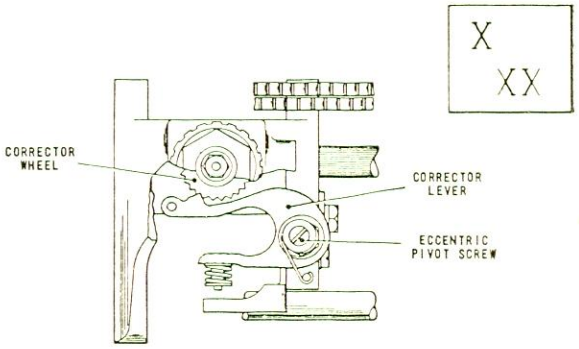


Fig 2.98. Typehead corrector mechanism.

32. Typehead Corrector Track Rail

Check

32.1 Depress the letter "X" key or, if the machine has no keyboard, set up the letter "X" combination (MSMMM) on the pins. Lift the translator clutch abutment and turn the machine by hand until the typehead moves forward to print. Press the typehead casting forward so that the typehead moves towards the platen. Using a slip gauge, check that when the corrector lever, **Fig 2.98**, is fully engaged with the corrector wheel, the typehead is within 100–125mil of the platen. Check for this condition with the typehead at both ends of its traverse.

Action

32.2 If this condition is not present, it will be necessary to adjust the height of the corrector track rail, **Fig 2.100**. To do this, slacken the two screws securing the track rail and adjust the height of the rail by means of the two shouldered pins. When the correct height is achieved, tighten the track rail securing screws.

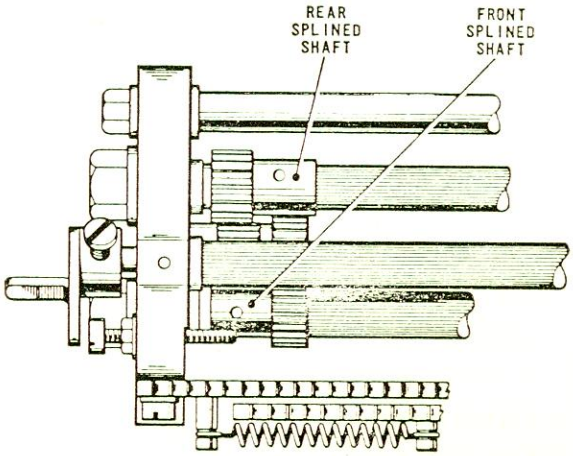


Fig 2.99. Typehead carriage-plan view.

33. Ribbon Unit Pawls

Check

33.1 Remove the ribbon spools. Depress any printing key or, if the machine has no keyboard, set up any printing combinations on the pins. Lift the translator clutch abutment and turn the machine by hand until the printing action has taken place. Press the typehead casting so that the typehead is held against the platen, and rotate the ratchet wheel, **Fig 2.101**, against the retention pawl. Check that there is now a clearance of 5–10mil (dimension "az") between the face of the feed pawl and the face of the next tooth in the ratchet wheel. If no adjustment is required, refit the ribbon spools.

Action

33.2 To adjust, slacken the two screws securing the pawl mounting bracket and move the bracket until dimension "az" is satisfied. Tighten the bracket screws and refit the ribbon spools.

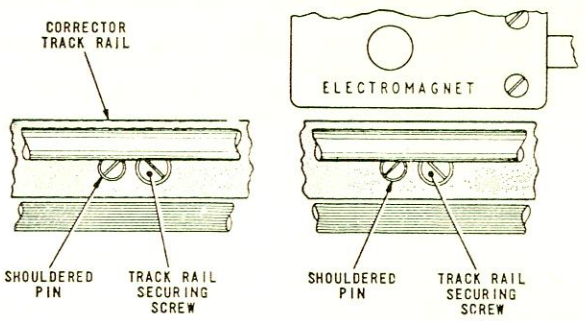


Fig 2.100. Typehead corrector track rail.

34. Ribbon Jumper Arm

Check

34.1 Depress any printing key or, if the machine has no keyboard, set up any printing combination on the pins. Lift the translator clutch abutment and turn the machine by hand until the printing action has taken place. Press the typehead casting so that the typehead is held against the platen and check that the upper edge of the ribbon is approximately 30mil above the type face which is in contact with the platen.

Action

34.2 If this is not so, slacken the two screws securing the jumper arm, **Fig 2.102**, and adjust the arm until the above condition is satisfied. Tighten the arm screws.

35. Typehead Height—Final Setting

Check

35.1 Print a line consisting of all the characters on the top layer of the typehead, then print alongside a line consisting of all the characters on the second layer of the typehead and a further line of top layer characters. Using the top layer as a reference, check that the second layer is at the correct height. Check also that the upper and lower legs of the characters are of equal density.

35.2 Repeat this procedure with the third and bottom layers in turn, using the top layer as the reference level each time.

Action

35.3 If the bottom layer is high with respect to the reference level, slacken the screws securing the stop block, **Fig 2.103**, and move the block towards the typehead lift rack until the correct height is obtained. Tighten the stop block screws.

36. Contact Springs

(a) Code, Start and Stop Contacts

Check

36.1 Check that the left-hand face of the contact plate, **Fig 2.104,** is clear of the tips of each contact stud by a maximum of 10mil (dimension "w") and that the tips of the studs are in alignment.

36.2 Check that there is a clearance of 20–25mil (dimension "x") between each mark contact blade and its associated tongue.

36.3 Check that the following spring pressures are within the limits indicated:

(i) A force of 2–2½oz (57–72g) applied to the tip of each tongue to move it clear of its associated space contact blade.

(ii) A force of 1–1½oz (28–43g) applied to the tip of each mark contact blade to move it away from its associated buffer.

(iii) A force of 2½–3oz (72–85g) applied to the tip of each code contact blade to move it away from its associated buffer.

(iv) A force of 2½–3½oz (72–99g) applied to the tip of each read-out contact blade to cause its contact to engage the code contact blade.

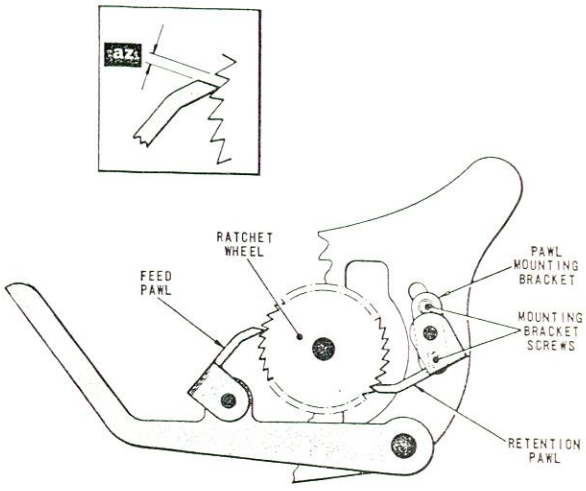


Fig 2.101. Ribbon feed and retention pawls.

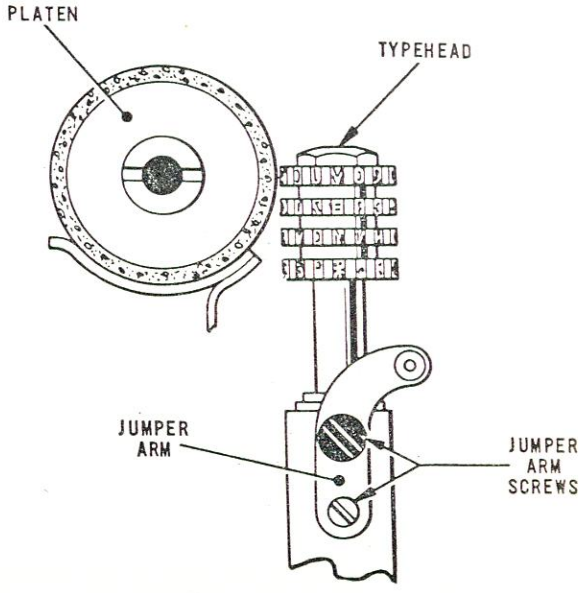


Fig. 2.102. Ribbon jumper arm.

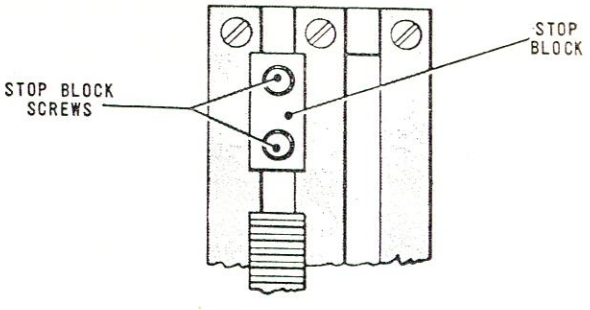


Fig 2.103. Typehead lift rack and stop block.

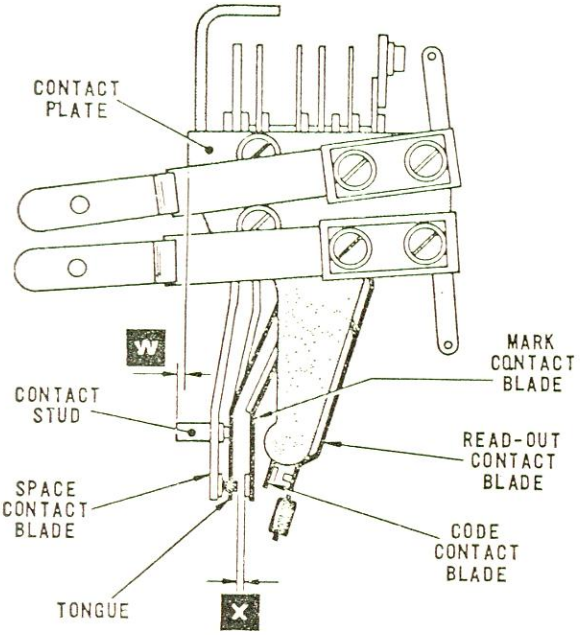


Fig 2.104. Transmitter unit—front view.

Action

36.4 To adjust, set the appropriate contact blades until all the conditions are satisfied.

(b) Send-Receive Contacts

Check

36.5 Check that the following conditions are present:

(i) A force of 1–1½oz (28–43g) applied to the tip of the receive contact blade, **Fig 2.105**, causes the blade to move away from its buffer.

(ii) There is a clearance of 25–35mil (dimension "y") between the receive contact blade and the tongue.

(iii) A force of 1–1½oz (28–43g) applied to the tip of the tongue causes the tongue to engage the receive contact blade.

Action

36.6 To adjust, set the appropriate contact blades until all the conditions are satisfied.

37. Keyboard Combination Bar Reset

Check

37.1 Slacken the four screws (two at each end) securing the keyboard mask and lift off the mask. Depress the letter "X" (MSMMM) key, lift the translator clutch abutment and turn the machine slowly by hand until the top of No. 1 transmitter lever (third from the rear), **Fig 2.106**, is fully in.

37.2 Continue to turn the machine, watching No. 2 transmitting lever (fourth from the rear) move slowly inwards, and stop turning when Nos. 1 and 2 transmitter levers are in line. Check, by observation, that the combination bar lever latch has now reset. If no adjustment is required, refit the keyboard mask and secure it with its four screws.

37.3 Continue to turn the machine until the combination bar reset lever, **Fig 2.107**, is on the highest point of the

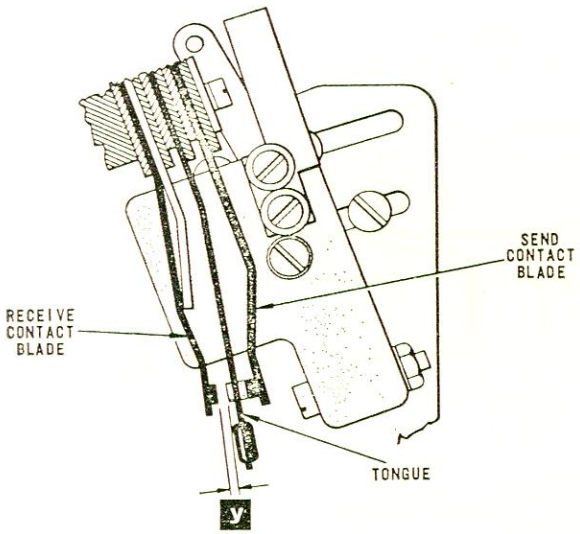


Fig 2.105. Send-receive contacts.

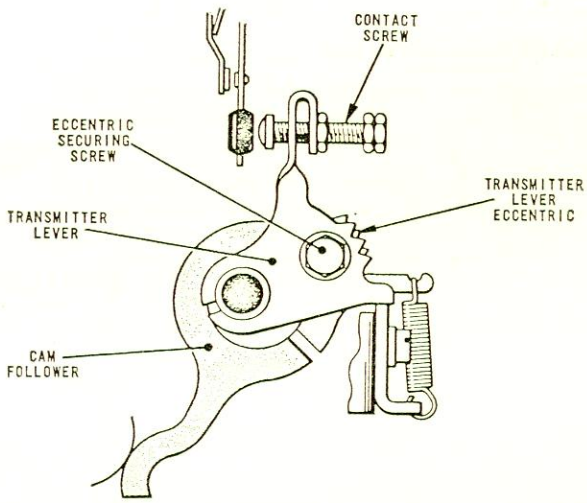


Fig 2.106. Transmitter lever/cam assembly.

reset cam. Depress each key in turn and check that with the key held down it is possible to move the roller on the reset lever away from its cam by a minimum of 5mil.

37.4 Return the machine to the rest position and depress the letter "Z" (MSSSM) key. Pull the reset lever away from its cam and check, by observation of the pushrods, **Fig 2.108**, that Nos. 1 and 5 combination bars start to reset simultaneously. This is to ensure that the reset lever mounting bracket, **Fig 2.107**, is positioned squarely with respect to the ends of the combination bars.

Action

37.5 To adjust, depress any key, lift the translator clutch abutment and turn the machine by hand until the condition set up in Check 37.3 is reached. Slacken the two screws securing the reset lever mounting bracket and move the bracket until the roller on the reset lever can be pulled away from its cam by an estimated 10mil. Lightly clamp the bracket screws.

37.6 Repeat Checks 37.1 and 37.4 and, if necessary, refine the adjustment of the mounting bracket until all the conditions are satisfied. Tighten the bracket screws fully and refit the keyboard mask.

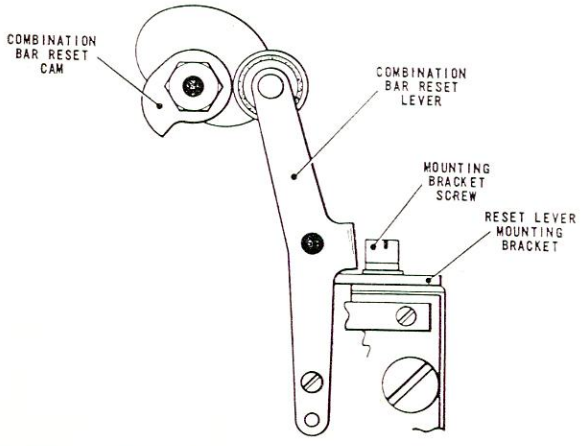


Fig 2.107. Combination bar reset mechanism.

38. Selector Bar/Selection Pin Alignment

Check

38.1 With the machine in the rest position, check that the selector bars, **Fig 2.109**, are in alignment with the selection pins. Lift the translator clutch abutment and turn the machine by hand until the pin-box has moved to its alternative position and re-check the alignment of the bars and the selection pins.

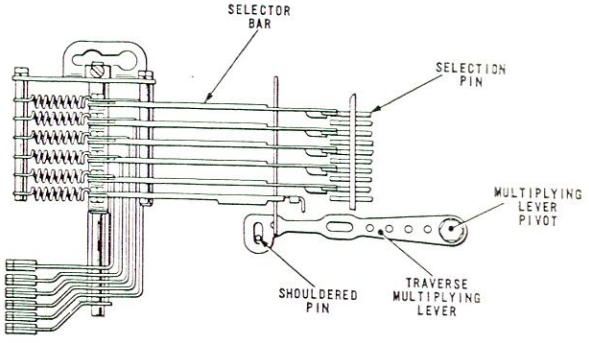


Fig 2.109. Selector bar/selection pin alignment.

Action

38.2 To adjust, remove the operation counter, slacken the nut securing the shouldered pin and the nut securing the multiplying lever eccentric pivot. Taking up any free play in the direction of the traverse, reposition the multiplying lever to obtain the required alignment. Position the shouldered pin so that play between the pin and the ends of the slot in the multiplying lever is equal in both positions of the pin-box. Tighten both nuts and refit the operation counter.

39. Selector Bar/Selector Pin Clearance

Check

39.1 Depress the letters (MMMMM) key and, by applying finger pressure to each of the five selector bars in turn

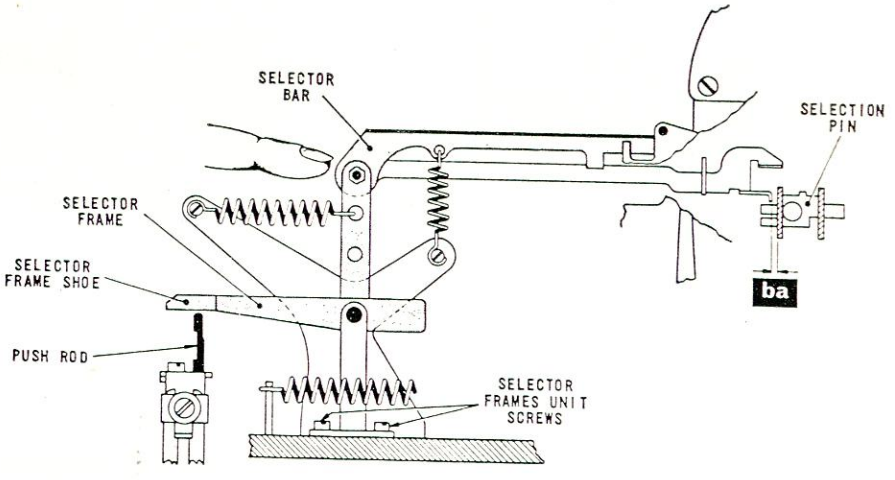


Fig 2.108. Selector bar/selection pin clearance.

as shown in **Fig 2.108**, check that there is an estimated free movement of 5–20mil (dimension "ba") between the end of each bar and the corresponding selection pin.

39.2 Lift the translator clutch abutment and turn the machine by hand until the pin-box has moved to its alternative position and repeat Check 39.1.

Action

39.3 To adjust, slacken the four screws (two only shown in the figure) securing the selector frames unit and reposition the unit until the correct clearance is obtained. Tighten the four screws.

Check

39.4 Check that the five selector frame shoes and the push rods are in alignment.

Action

39.5 To adjust, set the selector frames to obtain alignment.

40. Lag Weight Release Lever Stop

Check

40.1 With the machine in the rest position, check that there is an estimated engagement of 30–45mil (dimension "bb") between the latching face of the lag weight release lever, **Fig 2.110**, and the projection on the lag weight hook plate.

Action

40.2 To adjust, slacken the nut clamping the release lever eccentric stop and turn the stop until dimension "bb" is set up. Secure the stop in this position with its clamp nut.

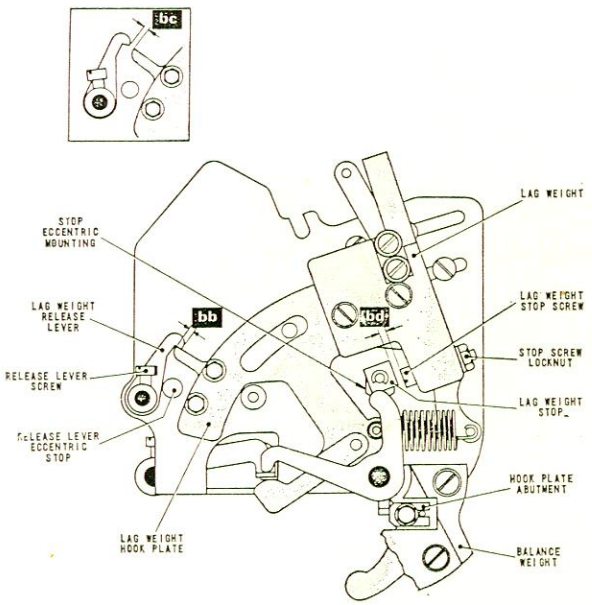


Fig 2.110. Lag weight mechanism.

41. Lag Weight Trip

Check

41.1 Hold the lag weight, **Fig 2.110**, to prevent it moving and depress any key on the keyboard. Check that the lag weight release lever is now lifted clear of the projection on the lag weight hook plate by an estimated 15–45mil (dimension "bc"—inset).

41.2 If an answer-back unit is fitted, check that the lifting of the release lever by the action of the answer-back wards causes a similar clearance (dimension "bc"—inset) to be set up between the release lever and the hook plate.

Action

41.3 To adjust, slacken the screw securing the release lever and reposition the lever on its shaft until the above conditions are achieved. Tighten the release lever screw.

42. Lag Weight Movement

Check

42.1 Ensure that the translator camshaft is in the rest position. Depress the letter "X" (MSMMM) key and check that the lag weight hook plate, **Fig 2.110**, is now in contact with the lag weight stop.

42.2 Turn the machine slowly by hand until the function reset bar starts to move towards the rear of the machine. Check that the lag weight hook plate is still in contact with the lag weight stop.

42.3 Continue to turn the machine slowly by hand until the typehead moves forward to print. Check that there is now a clearance between the plate and the stop.

Action

42.4 If this is not so, return the machine to the rest position and remove the transmitter unit. Depress the letter "X" (MSMMM) key again and turn the machine slowly by hand, this time until the function reset bar has just ceased to move towards the rear of the machine.

42.5 With the machine in this position, slacken the nut clamping the stop and turn its eccentric mounting (using the lower half of the eccentric movement) until the stop is just touching the edge of the plate. Tighten the clamp nut and refit the transmitter unit.

While carrying out this adjustment, hold the stop with a spanner to prevent it rotating.

Check

42.6 Continue to turn the machine by hand until the top of the lag weight is in its extreme left-hand position. Check that there is now a clearance of 2–6mil (dimension "bd") between the stop and the lag weight stop screw.

Action

42.7 If necessary, slacken the stop screw locknut and adjust the stop screw until dimension "bd" is set up. Tighten the locknut.

43. Translator Trip From Lag Weight

In the following adjustment it is important to ensure that the translator trip occurs on the last 30mil of movement of the top of the lag weight, otherwise the lag weight timing

may be upset—Adjustment No. 47 refers. If the translator trip does not occur within this limit, re-check Adjustment Nos. 11 and 13 before attempting to adjust the translator trip from the lag weight.

Check

43.1 Depress any key on the keyboard and, with the lag weight hook plate, **Fig 2.110**, against the lag weight stop, check that there is a maximum clearance of 3mil (dimension "be") between the starter arm pin, **Fig 2.111**, and the worm wheel.

Action

43.2 To adjust, return the machine to the rest position and remove the balance weight, **Fig 2.110**. Slacken the screw clamping the abutment and move the abutment to its extreme right-hand position. Depress any key again, and, with the lag weight hook plate held against the stop, adjust the abutment until the required clearance between the starter arm pin, **Fig 2.111**, and the worm wheel is obtained. Clamp the abutment, **Fig 2.110**, in this position with its screw and refit the balance weight.

44. Send-receive Delay Lever Clearance

Check

44.1 Depress any key on the keyboard and turn the machine by hand until the send-receive delay lever, **Fig 2.111**, is in its lowest position. Check that there is now a radial clearance of 15–45mil (dimension "bf") between the delay lever and the left-hand side of the orientation casting.

Action

44.2 To adjust, slacken the delay lever clamp screw, hold down the delay arm and reposition the delay lever until the correct clearance is achieved. Tighten the clamp screw.

45. Send-receive Switch Contacts

Check

45.1 With the machine in the rest position and the delay arm, **Fig 2.112**, fully restored by the crawler clutch and in contact with the lag weight extension, check that there is a clearance of approximately 10mil (dimension "bg") between the receive contact blade and its buffer plate.

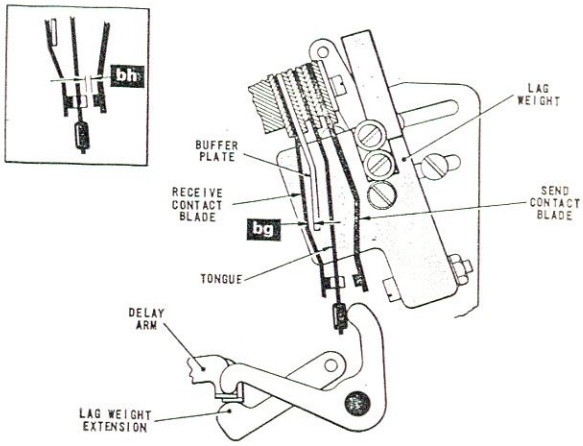


Fig 2.112. Send-receive switch contacts.

If the delay arm and lag weight extension are not in contact with each other when the machine is in the rest position, switch on the motor for a few seconds to allow the slow-return crawler clutch mechanism to reset.

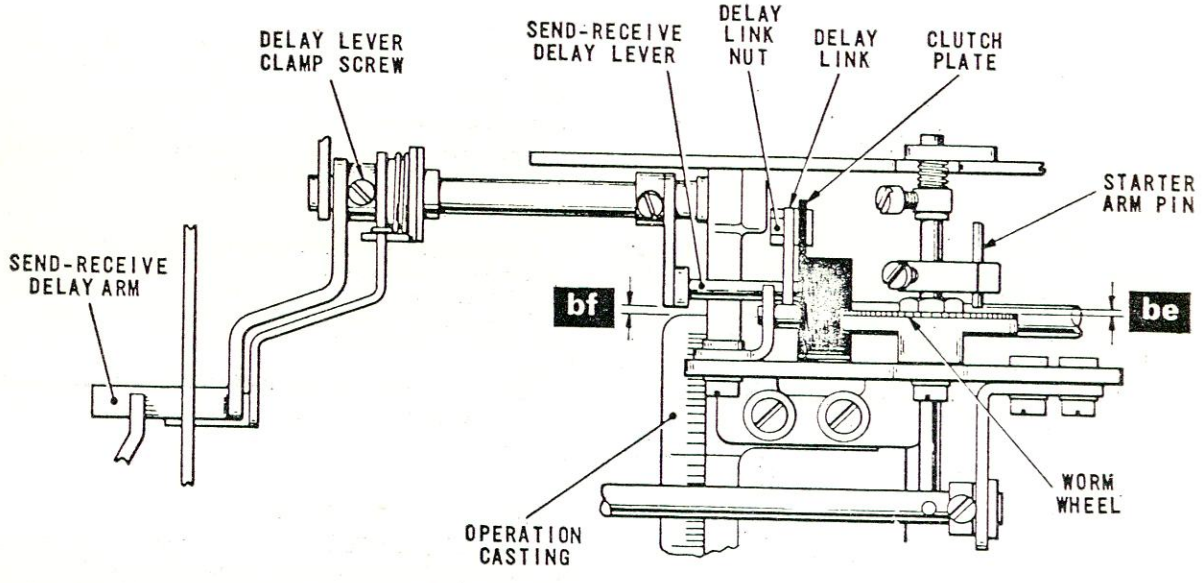


Fig 2.111. Send-receive switch delay linkage.

Action

45.2 If necessary, set the buffer plate to achieve dimension "bg".

Check

45.3 Hold the lag weight to prevent its movement and depress any key on the keyboard. Allow the lag weight to move slowly to the right until the receive contact blade is against its buffer plate but the tongue and receive contacts are still made. Check that there is now a clearance of 10–15mil (dimension "bh"—inset) between the tongue and the send contact blade.

Action

45.4 To adjust, set the send contact blade until dimension "bh" is achieved.

Check

45.5 Release the lag weight so that the tongue fully engages the send contact blade. Check that a force of 1–1½oz (28–43g) applied to the tip of the tongue will move the tongue over to the receive contact blade.

Action

45.6 To adjust, set the tongue, ensuring that the send contact follows the movement of the tongue and maintains contact with it over the first part of its traverse. Re-check Adjustments 45.1 and 45.3.

46. Send-receive Contact Delay

Check

46.1 With the machine in the rest position and the delay arm, **Fig 2.112**, in contact with the lag weight extension, trip the lag weight by depressing any key on the keyboard. Turn the machine by hand until the translator clutch has completed one revolution and check that the tongue is still touching the send contact blade.

46.2 Lift the translator clutch abutment, turn the machine by hand and check that, during the second revolution of the transfer clutch, the tongue breaks from the send contact between the changeover of Nos. 4 (second from the front) and 5 (nearest the front) transmitter levers, **Fig 2.106**.

Action

46.3 If the contact changeover is early, slacken the nut securing the link, **Fig 2.111**, to the clutch plate and slide the link to the right. Tighten the nut. Repeat Checks 46.1 and 46.2 and, if necessary, Adjustment 46.3 until both the above conditions are satisfied.

46.4 If the contact changeover is late, repeat Adjustment 46.3 but this time slide the link to the left.

If the conditions in Checks 46.1 and 46.2 cannot be met by carrying out the above adjustments, excessive backlash may be present in the gearing that drives the crawler clutch drum. The end-play in the vertical spindle should not exceed 2mil and is maintained by raising or lowering the worm spindle bearing. If the conditions still cannot be met, refine Adjustment No. 44 and then repeat Adjustment No. 46.

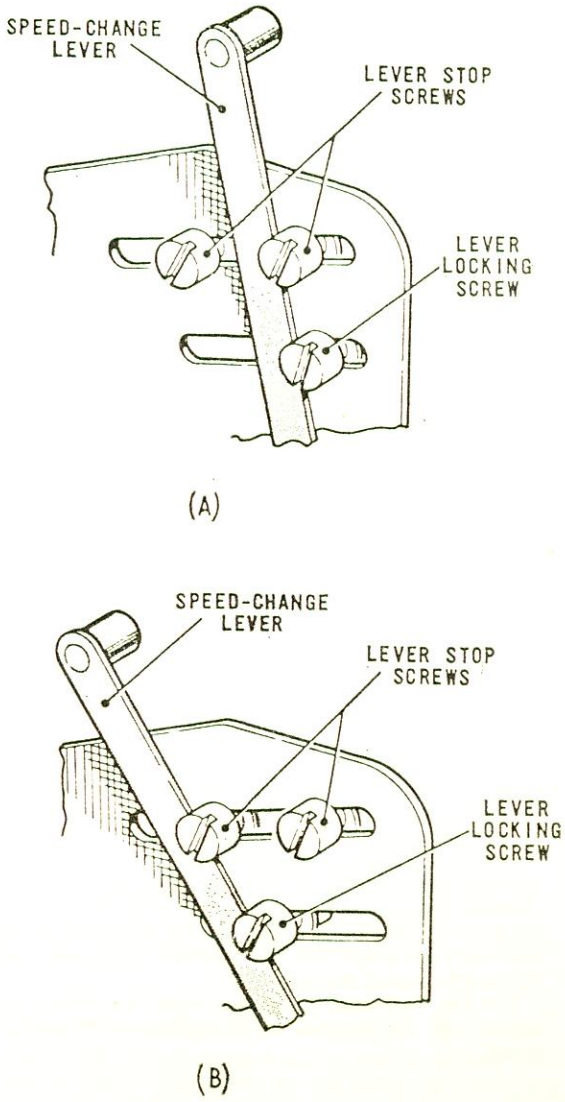


Fig 2.113. Speed-change lever positions.

47. Lag Weight Transit Timing

The anchor of the lag weight spring is on the tail of the speed-change lever, **Fig 2.113**. On dual-speed machines the lag weight transit timing, and thus the length of the stop signal, should be set to suit the required speed of operation by positioning the speed-change lever against one of its two stop screws. The positions of the stop screws are set in the factory and will not normally require attention. If, however, a new lag weight spring is fitted at any time it may be necessary to reposition the stop screws by carrying out the following procedure overleaf:

Check

47.1 Switch on the motor and check its speed.

47.2 On dual-speed machines, check that the correct set of gears is engaged.

47.3 Check that the speed-change lever is abutting against its appropriate stop screw for the required speed of operation, ie

(*a*) For 45/50 baud operation, as shown in **Fig 2.113a**.

(*b*) For 75 baud operation, as shown in **Fig 2.113b**.

47.4 Ensure that the feed change lever, **Fig 2.85**, is in the single feed position, ie towards the rear of the machine. Move the pressure roller release lever towards the rear of the machine so that the paper will not feed. Mark a pencil line on the platen knob boss and a corresponding mark on the platen unit end-plate.

47.5 Switch on the motor, run out line feed from the keyboard and check that the number of revolutions the platen makes over a period of one minute is as follows:

(*a*) On 45 baud operation—$12\frac{1}{6}$ revolutions.

(*b*) On 50 baud operation—$13\frac{1}{3}$ revolutions.

(*c*) On 75 baud operation—20 revolutions.

Action

47.6 If the correct number of revolutions is not obtained, move the speed-change lever, **Fig 2.113**, towards the front of the machine so that it is freed from its stop screws. On single-speed machines, it may also be necessary to slacken the locking screw located in the bottom slot in the translator unit rear frame, and move the screw to one side so that the speed-change lever can be freely adjusted.

Check

47.7 Move the speed-change lever slightly and repeat Check 47.5. Check whether it is now possible to approach the correct figure more closely without causing the translator clutch to cease tripping the machine.

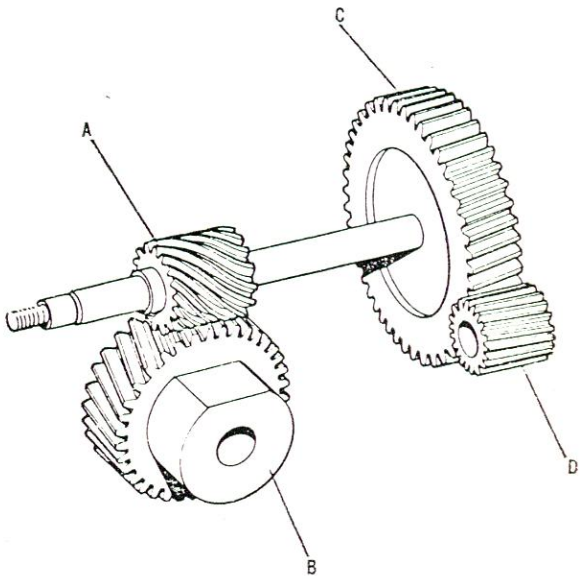
47.8 If improvement appears to be possible, hold the speed-change lever in its new position and allow the machine to shut down under the action of the starter switch mechanism. Depress any key on the keyboard (except Run Out) and check that the translator clutch abutment lifts and the motor starts up.

47.9 On dual-speed machines, repeat the above procedure with the machine set to operate at its alternate speed.

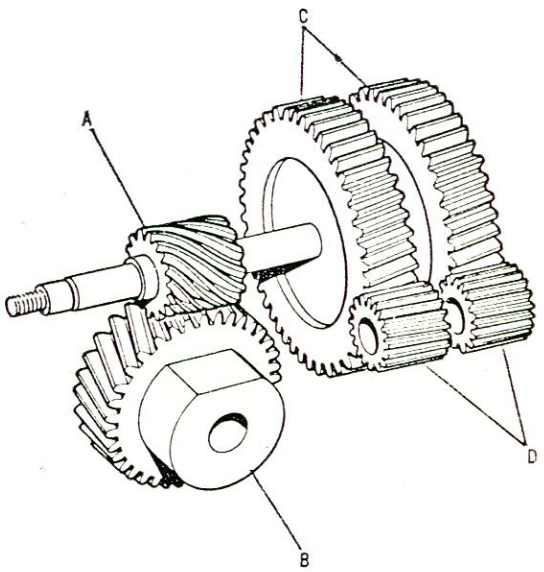
Action

47.10 Refine the position of the speed-change lever until all the above conditions are satisfied, and then secure the lever in its new position with its stop screws. On single-speed machines, return the locking screw to its position at the right-hand side of the lever.

47.11 Restore the pressure roller release lever towards the front of the machine so that the paper will again feed.



USED WITH
SINGLE SPEED SELECTOR UNIT S4278



USED WITH
GEAR BOX SELECTOR UNIT S4279

Right: Fig 2.114. Model 75 drive gears. (See Appendix for Model 75 gear details)

THE CREED 444 TELEPRINTER

General

Designed primarily for use in private wire and Telex teleprinter communications systems, the new Model 444 (or GPO Type 15) teleprinter represents a significant advance in teleprinter technology. It has been built to satisfy the stringent CCITT standards and is compatible with all other teleprinters and circuits conforming to these standards. It will operate in either the simplex or the duplex mode at speeds of 50 or 75 bauds.

The 444 can be converted from double to single current operation by means of a small electronic converter unit, which is available as an optional extra.

The printing mechanism consists of a type basket which moves from side to side in front of a stationary platen and can hold a maximum of 28 type bars, although 26 are standard. Printing in all common Indo-European alphabets

The Creed 444 teleprinter (courtesy ITT-Creed Ltd).

is possible and languages involving a right to left type basket traverse action can also be catered for. The length of line is from 69 to 75 characters and each character is printed as soon as it is received.

The machine can be fitted with a friction-feed platen or a sprocket-feed platen for use with marginally punched stationery.

A full range of optional facilities is available for use with the basic machine and these include tape punch and tape reader units, a code recognition unit (stunt box), automatic motor switch, paper low contacts, answer-back unit, tape low contacts, and motor on speed relay.

Construction

Robust unit construction has been employed in the manufacture of this machine. Each major unit is carried on its own casting or frame and is secured by no more than four screws. All castings are pressure diecast in aluminium alloy and are corrosion resistant. An extensive use has been made of plastic mouldings for both moving and static parts.

Two types of motor may be fitted, governed or synchronous. The governed types are series wound 3,750rpm ac single-phase, for any single voltage in the ranges 100–125V (5V steps), 200–250V (10V steps) at 40, 50 and 60Hz.

Series wound 3,000rpm dc governed motors are available if required for any single voltages in the ranges 100–125V (5V steps) 160V, 200–240V (10V steps).

Synchronous types are available for any voltage in the ranges 110–125V, 200–250V, 50Hz; 60Hz versions are available in the range 110–125V. Both versions run at 3,000rpm.

OUTLINE DESCRIPTION

1. Reception (Fig 2.115)

Signals from the distant teleprinter are received on a polarized electromagnet whose armature moves between "marking" and "spacing" stops in response to reversals in line current that compose the incoming code combination.

The "start" signal releases the selector unit cam sleeve which makes a half-revolution during which it converts the subsequent movements of the electromagnet armature into a static code setting on five two-state latches. Towards the end of this revolution, the selector unit releases the main cam shaft, and is itself brought to rest immediately afterwards by the "stop" signal.

The main cam shaft now transfers the code established sequentially on the selector unit latches to the link unit and code control unit where it is latched and stored in parallel. Once this has been done the selector unit is free to accept another code combination.

In the code control unit the stored code is conveyed simultaneously to the print selectors that select the required type from the type basket, and to the function unit where it is inspected to determine whether it is a "printing" code or a "functional" (non-printing) code such as "line-feed". If the code is found to be a "printing" code, the appropriate type bar is activated by a print bail, and its character is impressed on the paper; the "carriage feed" operation follows automatically. If the code is found to be a "non-printing" functional code, the print and feed operations are automatically inhibited, and the appropriate function is carried out.

2. Transmission (Fig 2.115)

Operation of the keyboard sets up the mark/space combination of the selected key on five groups of comb bars, and simultaneously activates a trip bar common to all keys, which releases the transmitter cam sleeve to make one revolution. During this revolution the transmitter mechanism inspects this code setting sequentially, and converts it into the train of mark/space electrical signals that make up the five-unit code for the depressed key. The transmitting mechanism, which electrically consists of a single, side-stable, change over contact, automatically inserts the "start" and "stop" signals at the appropriate time, and also switches the send/receive switch to "send" before beginning a transmission and returns it to "receive" when the transmission is concluded.

1. INTRODUCTION

The sections that follow outline the principle of operation of the major units of the Model 444 teleprinter. After listing

these units under the heading "General" below, and describing briefly the distribution of mechanical power, the "Principle of Operation" is given under the following main headings:

Keyboard	Ribbon Mechanisms
Transmitter	Automatic Motor Switch
Selection	Answer-back
Translation	Tape Punch
Two-colour Printing	Tape Reader

2. GENERAL

The Model 444 is a heavy-duty, page-printing teleprinter designed to operate at speeds up to 75 bauds. It is of unit construction and consists (in addition to the main base and left-hand and right-hand side frames) of the following major units and assemblies:

Keyboard Unit
Transmitter and Answer-back Unit
Main Cam Shaft
Link Unit
Code Control Unit
Function Unit
Type Carriage Unit
Carriage Feed Unit
Platen Unit
Motor
Lay Shaft
Automatic Motor Switch
Tape Punch
Tape Reader

3. DRIVE

The standard machine is powered by a 3,000rev/min synchronous motor which drives, via a lay shaft, a main drive shaft which in turn drives two units directly:

1. the selector unit, through a friction clutch, and
2. the carriage feed unit, by gears.

The combined keyboard transmitter and answer-back unit is driven from the lay shaft, by gears.

The main drive shaft also has a cam sleeve which performs the "translation" and printing operations, and provides power to operate the non-printing functions. The tape punch is driven by cam-riding levers from the main cam sleeve, the tape reader by a toothed neoprene belt from the transmitter drive shaft.

4. KEYBOARD UNIT

4.1 General (Fig 2.116)

The purpose of the keyboard unit is to produce from the depression of a single key a trip action to activate the transmitter, and also five simultaneous comb bar settings which are then interpreted by the transmitter into the electrical signals that make up the five-unit code of the selected key. The main components of the keyboard are shown in **Fig 2.116**; to avoid congestion on the illustration, only one of the five pairs of comb bars is shown, at A and B. Keybars C and D are held in a comb (not illustrated) and are pivoted at the rear end. At rest they are held above the comb bars by leaf springs E, as shown.

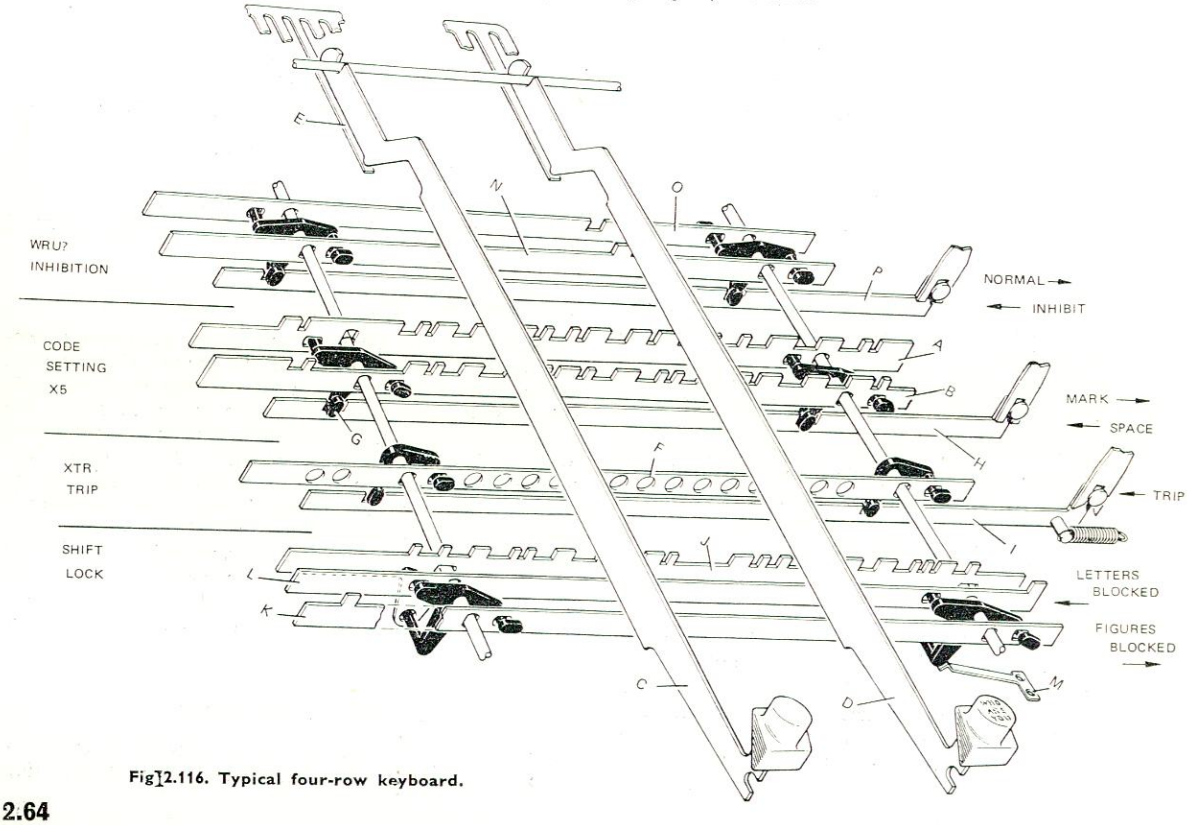


Fig 2.116. Typical four-row keyboard.

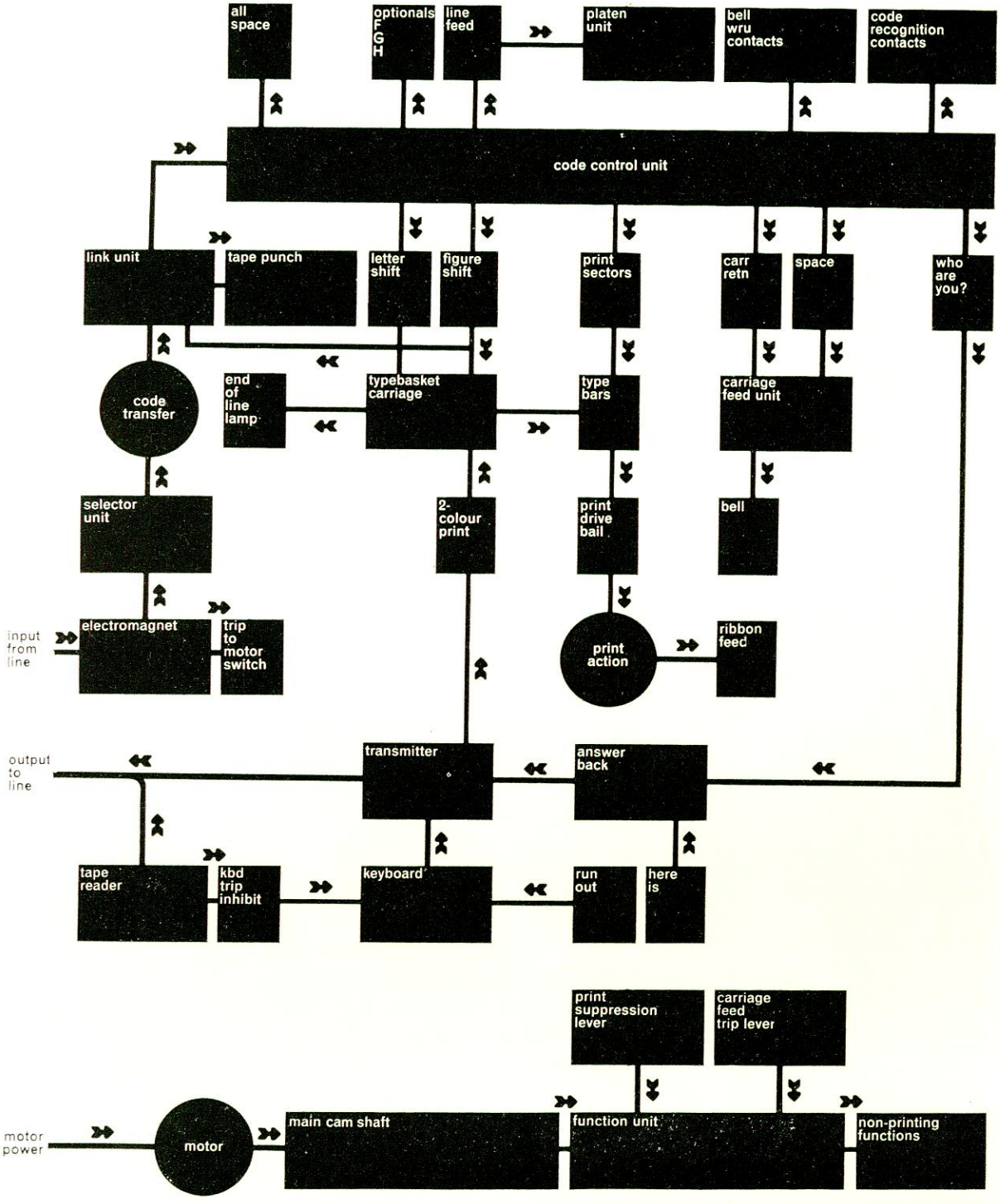


Fig 2.115. Creed model 444, block diagram.

4.2 Code Setting (Fig 2.116)

Operation of keybar C will press it down on the top edge of each of the five pairs of comb bars A and B, which are linked together at each end by the T-shaped levers G. The depressed keybar engages a tooth on comb bar A so depressing the bar and, at the same time, raising the other comb bar B which has a cut-out at this point. Levers G then turn counter-clockwise, so sliding link bar H to the right. (Because of the rocking action of these pairs of comb bars, and the interference of their teeth, the operator cannot depress two keys simultaneously.) Depending on the position of the teeth and cut-outs on the other four pairs of comb bars, their associated links H will slide to the left to set up a "mark" condition, and to the right for a "space" condition. The underside of the depressed keybar C also operates trip bar F which lies beneath all keys, sliding trip link I to the left. This movement releases the transmitter unit cam sleeve.

4.3 Case Shift (Fig 2 . 116)

Shift bar J can be positioned to block either "letters" keys, or "figures and symbols" keys. It is moved to the left (to block "letters" keys) when the "figures" keybar acts on tooth K, and to the right (to block "figures" keys) when the "letters" key acts on tooth L. Leaf spring M retains the shift bar in the position to which it was last set.

5. TRANSMITTER UNIT

5.1 Trip Action (Fig 2·117)

As described in paragraph 4, the operation of a keyboard key causes link bars H, **Fig 2.117**, to move to the left for "mark", and to the right for "space". These movements bring the top ends of the associated selection levers A to one side or the other of lock frame B. A simultaneous movement to the left by trip link C turns lever D clockwise, so pushing the step in the lower arm of trip latch E against trip lever F. The upper extension of lever F is thus pulled away from the right-hand end of detent G which turns clockwise to release clutch moving arm I. Arm I carries one end of a spring-steel band which is loosely wound around a continuously-driven drum. The other end of this band is anchored to the clutch back plate, a part of the transmitting cam sleeve. When arm I is released, a spring draws the clutch band tight around the drum, and the cam sleeve starts to rotate.

5.2 Code Transmission (Fig 2.117)

When the transmitting cam sleeve is at rest, the transmitter tongue J is at "mark" and the send/receive switch tongue at "receive". As soon as the sleeve starts to revolve, lever K is moved out and pivots toggle L to move its contacts to "send". Cam M then lowers frame B to lock the code set up on levers A, and in so doing, locks the keyboard. Normally common frame N is urged clockwise by its spring to rest against the sequential levers O. An extension at the rear of frame N positions carrier P, and hence the Y-shaped striker Q, as shown in the above illustration. As the cam sleeve rotates further, the first rise on cam R pushes striker Q up against the right-hand side of dolly S, which pivots counter-clockwise to move the contacts from "mark" to "space" and so initiate the spacing "start" signal. Dolly S is retained in this position by a spring loaded jockey roller Z. Twenty milliseconds later cam R lifts striker Q again, and by this time the first of the sequential cams on cam pack T will have presented a flat to sequential lever O. If lever A is set to "mark", ie top-to-right, sequential lever O will be able to follow its cam, and so turn counter-clockwise to push common frame N to the left. At the instant striker Q operates, frame N and carrier P will have moved the striker to the left, so that it will hit the left-hand side of dolly S. The dolly then turns clockwise to bring the transmitter tongue to "mark".

5.3 One or other of the space/mark actions is repeated for each of the remaining operations of the striker, the movements of the transmitter tongue being dictated by the position of common frame N. A sixth sequential lever O, which has no lever A, turns counter-clockwise at the end of each cycle to make the last operation of the striker produce the stop "mark" signal. Near the end of the revolution of the transmitter cam sleeve, the vertical cam of detent G is pushed to the right by a reset cam built into the clutch back plate, so lowering the left-hand end of the detent into the patch of the clutch moving arm I. As arm I engages the detent, the overshoot of the cam sleeve causes the clutch band to unwind and slacken its grip on the drum. Retention lever Y then turns counter-clockwise to wedge the clutch in the rest position.

5.4 Send/Receive Switch Delay (Fig 2.117)

Since the first "start" strike occurs some 10ms after the beginning of the 150ms transmitting cam sleeve revolution, at the end of which the send/receive switch returns to "receive", the "stop" signal would be cut short on switched simplex circuits if some means were not provided to hold the

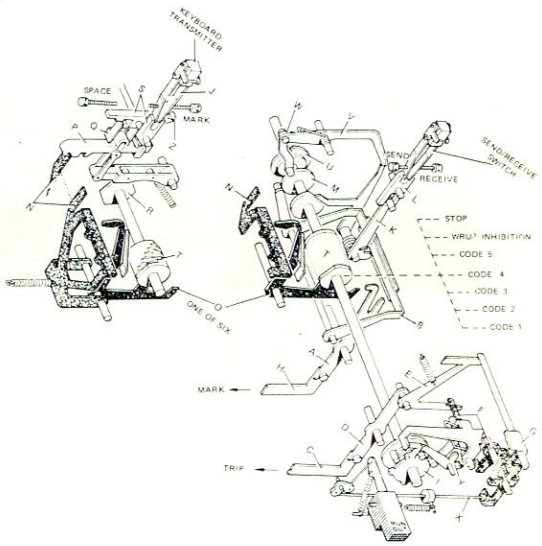
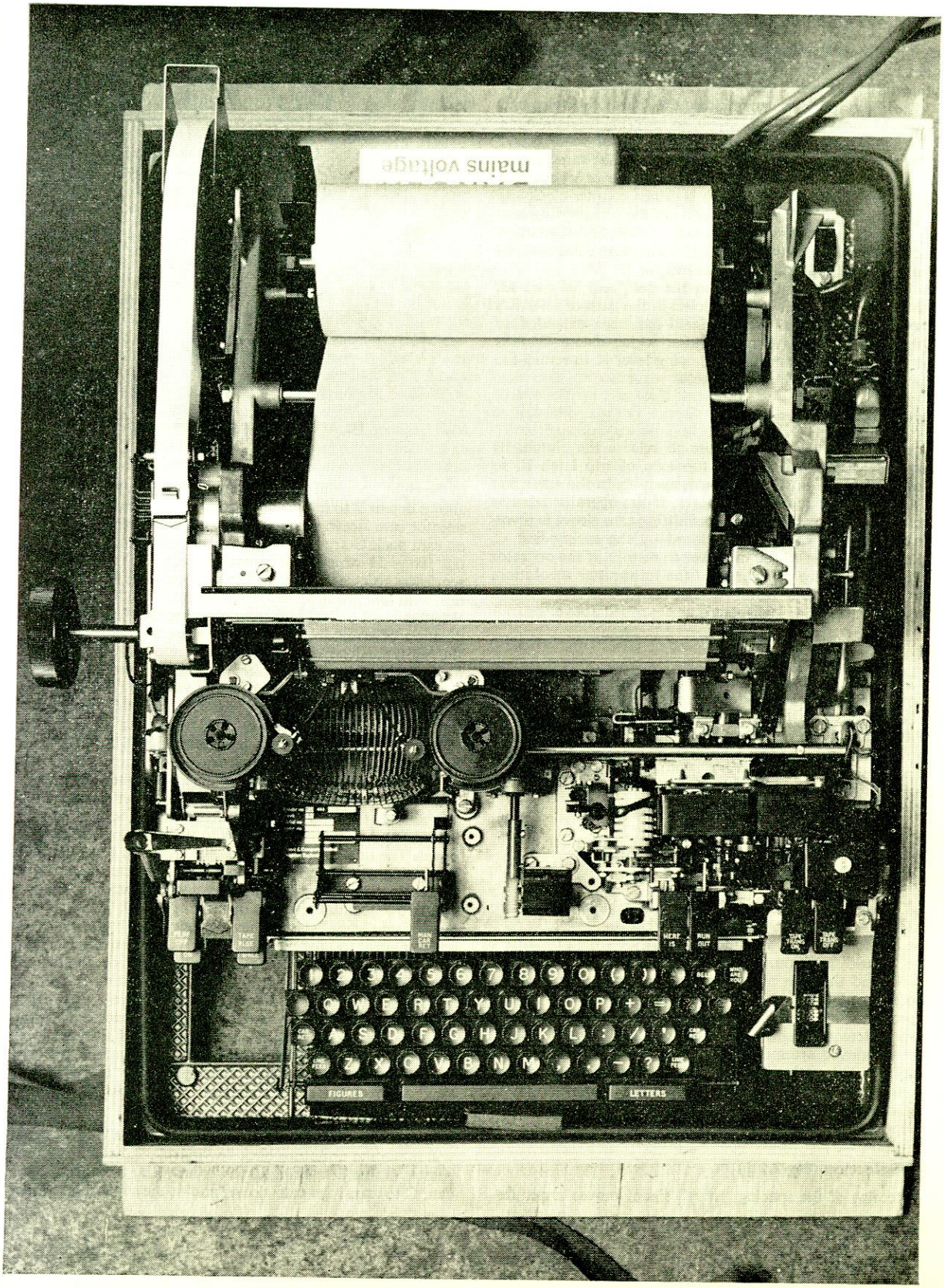


Fig 2.117. Keyboard transmitter mechanism.

RIGHT: **Creed 444 teleprinter, cover removed. (Courtesy ITT Creed Ltd.)**


mains voltage
FIGURES
LETTERS

send/receive switch tongue on "send" for a short time after the transmitting sleeve has come to rest. This extension is achieved as follows:

(*a*) During the transmission of the fourth code element, cam M turns lever V clockwise, so lowering its right-hand end into the path of the rear extension of send/receive lever K to block its return to "receive". The same movement of lever V lifts a detent W (fixed to lever V) out of a cut-out in delay disc U, which is driven counter-clockwise by a friction clutch, independently of the transmitting cam sleeve. Cam U takes about 75ms to make a half-revolution during which time the transmitting cam sleeve has reached the end of its cycle and come to rest.

(*b*) Detent W still rides on the periphery of cam U, however, and holds lever V down in the path of lever K's extension until the "stop" signal has been extended to the required 30ms duration, after which detent W falls into a cut-out in cam U so allowing lever K to return the send-receive switch to "receive".

5.5 Trip Reset (Fig 2.117)

As detent G pivots clockwise to release the clutch, its rear extension treads on the top arm of trip latch E, so moving the step on its lower arm away from the extension of trip lever F which then restores. If the operator releases the depressed key while the transmitting cam sleeve is revolving, trip lever D will be restored by the spring link C, allowing latch E and the trip lever to restore. If the operator holds the key down longer than the transmitter revolution, trip lever F is able to restore and bring the cam sleeve to rest because trip latch E is displaced as described above.

5.6 Run-out (Fig 2.117)

To repeat continuously the last code set into the keyboard comb bars, the operator depresses the "Run-out" key. This action pushes wire link X to the right and simulates the action of trip latch E on trip lever F, turning it counter-clockwise to release the detent, and holding the detent out to produce continuous "run away" transmission. Detent F restores and transmission comes to an end when the "Run-out" key is released.

6. SELECTION OPERATIONS

6.1 General (Fig 2.118)

The vertical armature of the side-stable polarized electromagnet A, **Fig 2.118**, moves to the right for "space" and to the left for "mark". The illustration shows the armature in the "mark" position. The selector cam sleeve (cams C, Q, G, R and the cam associated with lever I) is urged in a clockwise direction by two felt discs driven continuously from the main shaft, but normally held at rest by the lower arm of detent B engaging stop cam C. The pivot of detent B can be moved around the edge of stop cam C by rotating knob D. This action advances or retards the sensing operations of the selector unit with respect to the beginning of the "start" signal, and so provides a means for estimating the teleprinter's "margin".

6.2 Selection (Fig 2.118)

Receipt of the spacing "start" signal moves armature E

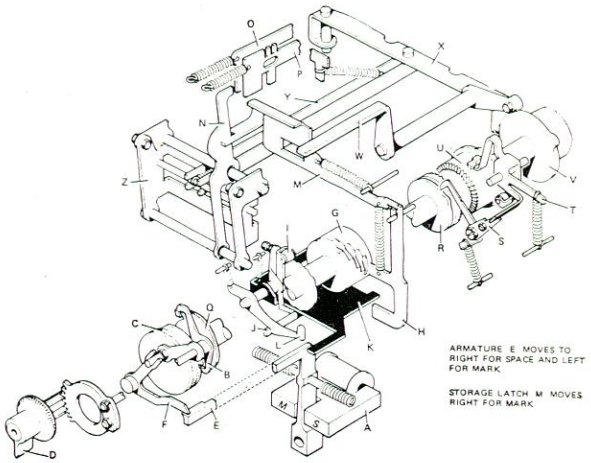


Fig 2.118. Selector unit mechanism.

to the right, so withdrawing support for trip lever F. Lever F allows detent B to move away from the stop cam C, and the selector cam sleeve starts to revolve. As it does so, five flats on cam pack G are presented in sequence to the five sequential levers H which then pivot inwards. In the same time sequence, recesses in the read cam allow lever I, in conjunction with bail lifting lever J, to lower read bail K, if it is free. Whether read bail K is free to move or not depends on the position of armature E. If the armature is at "space", ie to the right, the downward movement of read bail K is blocked, although lever J can still lower "space lock" lever L down the left-hand side of the armature to prevent it returning prematurely to "mark". In the "space" position, read bail K will not affect sequential levers H, which just pivot in and out beneath it in response to their cams. If the armature is at "mark", read bail K can move down, so engaging the lower arm of sequential lever H as it pivots inwards beneath bail K. The subsequent downward movement of lever H moves the projection at its top end away from the associated storage latch lever M, which then slides to the right to lock lever H down. The downward movement of read bail K also causes its sensing extension to pass down the right-hand side of the armature, so locking it against premature return to "space". The five sequential levers H operate at 30, 50, 70, 90, 110ms respectively from "start", they are driven down for "mark", and remain at rest for "space". At the end of the fifth element, the fleeting "blocked or free" responses of the sequential levers have been converted to a static code setting on storage latches M, whose left-hand ends enfold the five code transfer levers N. When a storage latch M is at "space", ie to the left, the upper cranked end of its associated transfer lever N is positioned opposite link O in the link unit. If latch M has been allowed to move to the right for a "mark" signal, the top of its transfer lever will be opposite link P.

6.3 After the end of the fifth code element, the "stop" signal will move the armature back to "mark". Reset cam Q then rotates detent B to bring its lower arm into the path of stop cam C to arrest the cam sleeve, and at the same time rotates

trip reset lever F counter-clockwise. The angled end of lever F displaces armature E slightly as it rises, but not sufficiently to move it to "space". The armature then moves back beneath lever F to maintain detent B in the stop position. At the end of this "selection" cycle, cam R turns trip lever S clockwise, so withdrawing the step from beneath the horizontal arm of detent T, which lifts to release ratchet clutch coupling U and connect power to the main cam sleeve which carries a series of cams one of which is cam V.

6.4 Code Transfer and Selector Reset (Fig 2.118)

A hump on the rear vertical face of cam V now presses lever X and linkage Y to the right. This movement causes frame Z, which is compliantly coupled to the left-hand end of linkage Y, to turn clockwise and press levers N against the links P and O. By this means, the code established on transfer levers N is passed to the link unit, where it is latched and stored. Cam V then rotates lever W to the link unit, where it is latched and stored. Cam V then rotates lever W counter-clockwise to press all the storage latches M to the left, so resetting the latches of any sequential levers H that had been set to "mark". The selector unit is now ready to respond to the next five-unit code group, while the main cam sleeve is translating the code set up on the link unit.

6.5 Link Unit (Fig 2.119)

The link unit consists of five pairs of links similar to R and S, **Fig 2.119**, and a shift link (shown at R on **Fig 2.122** and described in Section 4). The illustration shows link S held in the "mark" position by latch A. When a transfer lever P takes up a "space" position opposite link R, and then moves forward, the subsequent inward movement of link R turns latch A clockwise (via pin C) so releasing link S which is then restored to the left by its spring. Latch A is then urged against the bottom of the latching surface (at the end of leader line S) by the spring on link R. A second "space" strike on link R will be ineffective. When a transfer lever P is set to "mark" to bring it opposite link S, its subsequent forward movement sets link S to the marking position where it latches, as shown in **Fig 2.119**. A subsequent "mark" strike on link S will be ineffective.

7. TRANSLATION OPERATIONS

7.1 Principle of Printing Code Translation (Fig 2.119)

The right-hand of each link S, **Fig 2.119**, is connected to a bellcrank D which simultaneously controls (in conjunction with bellcrank F) the vertical movement of code slats W which select the required type, and the horizontal movement of comb bars H which select the non-printing functions such as "carriage return". Code slats W have a channel along their top edges in which run the rollers of the five selector bellcranks K that control the type basket code sectors N, swinging the sectors to the right for "mark", and to the left for "space". Arranged across sectors N are the code seeker bars O, one for each two printing characters. These bars are spring-loaded down on to printing bail Q, which holds them just clear of the sector teeth. All incoming codes are passed to sectorsN, but only when it is a "printing" code will print bail T move to the rear carrying with it type bail Q. All the seeker bars are thus lowered on to the code sectors N, but only one will find a path through the teeth and drop low enough for its notch Y to catch on type bail Q. Further rearward movement of bail Q will swing the required type bar V, via link U, out of the type basket and up on to the ribbon and paper.

7.2 Principle of Function Translation (Fig 2.119)

Function control levers, such as J, **Fig 2.119**, lie beneath the five comb bars H which are moved to the left for "mark", and to the right for "space" by bellcrank D. When a code is set up on the teeth below comb bar H, the control levers J are allowed to turn counter-clockwise by a bail that normally

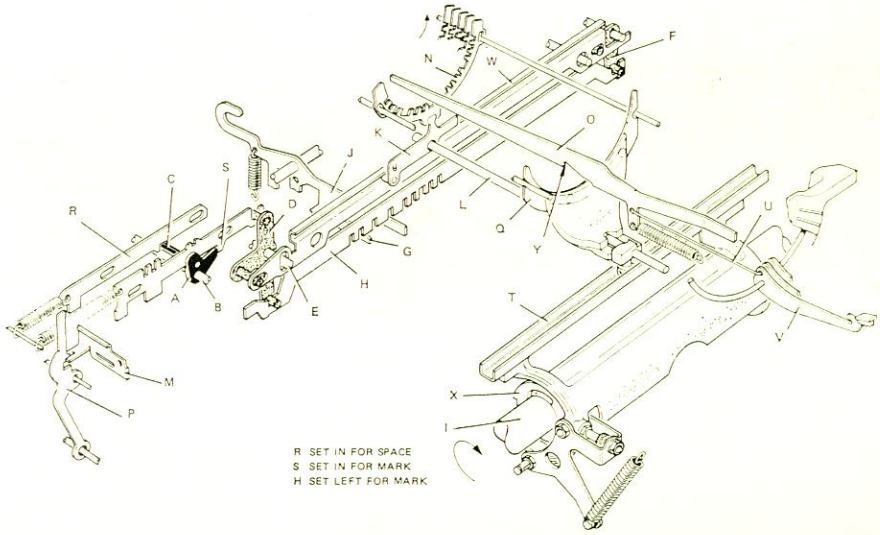


Fig 2.119. Link unit and typebar selection unit.

rests on lower arm G of lever J. The upper horizontal arm of lever J then senses the pattern of the comb bar teeth. If the setting on comb bars H is for a "printing" code, there will be no path across the teeth, and the function control levers will be lowered again. Carriage feed takes place automatically after the printing operation. If the code is that of a non-printing function, a path will open across the comb bar teeth, and the selected function control lever will move up into it. This extra counter-clockwise motion of lever J has three consequences: (1) its lower vertical arm (not illustrated) triggers the appropriate machine function, (2) carriage feed is suppressed on functions other than space, and (3) printing action is suppressed.

7.3 Print and Carriage Feed Control on Functions (Fig 2.120)

(*a*) Print: The rear horizontal arm of print suppression lever A, **Fig 2.120**, is tensioned on to the lower horizontal arms E1 of function control levers E. In this "unselected" position of levers E, the front end A1 of suppression lever A is positioned above arm D of print bail M. The printing bail is therefore free to operate. When any function control lever E is selected, its lower arm E1 in swinging upwards pivots suppression lever A clockwise to bring its front extension A1 down into the path of arm D, so blocking print channel M and preventing the printing action.

(*b*) Carriage feed: When a printing code is set up on the comb bars that lie above the function control levers E, no lever is selected; carriage feed trip lever G (black) is thus free to turn counter-clockwise, horizontal arm G1 passing over the top of the upper horizontal arms of levers E. The lower vertical arm of lever G then moves forward, sliding link H to the right to displace latch I from beneath arm J1 of carriage feed clutch detent J. Ratchet clutch K then engages its driving members, and rotates the feed shaft L through a half-revolution during which the type carriage is fed along $\frac{1}{10}$in. When a non-printing functional code is set up on the comb bars, one of the control levers E will be selected, and will move counter-clockwise. The upper horizontal arm of lever E will thus move up into the path of arm G1, preventing carriage trip lever G from rotating, and thus inhibiting the "carriage feed" operation.

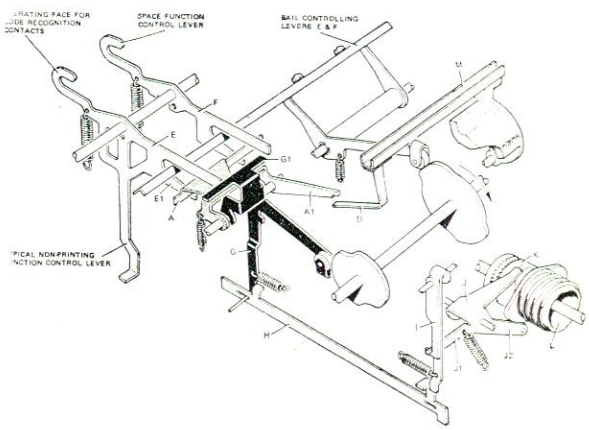
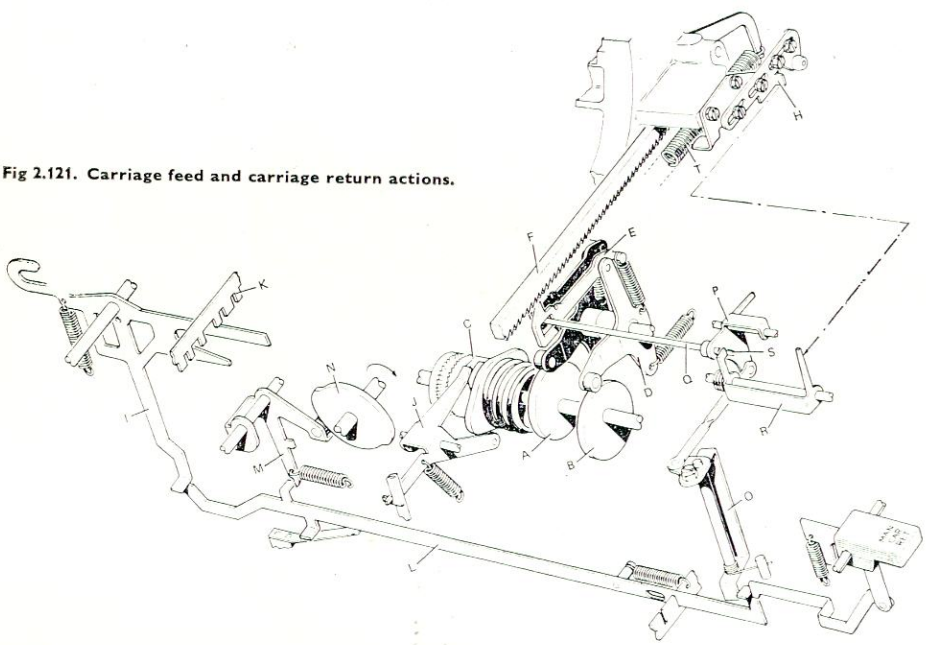


Fig 2.120. Print inhibition and carriage feed trip actions.

(*c*) Letter space: The "letter space" operation on receipt of the SSMSS code is a special case of a "function" that requires "feed" but not "print". A special "space" function control lever F is provided to produce this effect. When selected by the "space" code, its lower horizontal arm

Fig 2.121. Carriage feed and carriage return actions.



engages print supression lever A, turning it to block print channel M and so prevent printing, but lever F is located too far to the right for its upper horizontal arm to affect the carriage trip lever's arm G1. Lever G can therefore operate normally, and feeds a trip action to detent J to initiate a "carriage feed" operation.

7.4 Carriage Movements (Fig 2.121)

(*a*) Feed action: As explained in paragraph 7.3*b* above, the carriage feed detent J, **Fig 2.121**, is released for any printing code, and for "space", so permitting ratchet clutch C to engage and drive the carriage feed cam sleeve for a half-revolution during which it feeds the type carriage along one character space. The cam sleeve carries two cams A and B

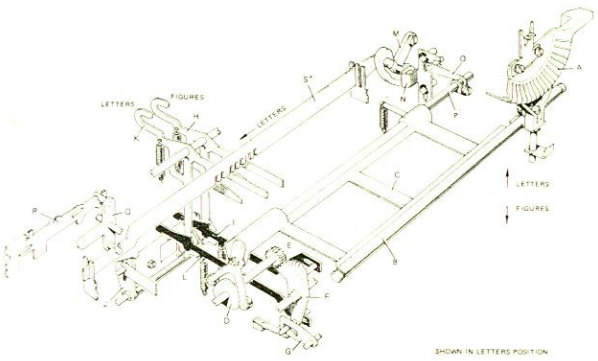


Fig 2.122. Letters/figures shift mechanism.

whose high points are 180 degrees out of phase. These cams drive two feed levers D, each carrying a feed pawl E, spring-loaded against the feed rack F that is assembled on the type carriage casting assembly. On one half-revolution of the cam sleeve the front pawl moves to the right, drawing the carriage with it, until the front pawl moves into the next tooth on the rack to retain the feed movement. In the next revolution of the cam sleeve, the carriage is retained on the rear pawl while the front pawl E draws the carriage to the right. End-of-line indication is given by an adjustable roller on plate H, mounted on the type carriage casting. This roller depresses a plate mounted behind the transmitter unit, and so operates a microswitch to light a signal lamp for the operator.

(*b*) Carriage return: The type carriage can be returned at any point along the line either on receipt of the "carriage return" code from line, or by local operation of the "Manual Carriage Return" key. Receipt of a "carriage return" code (SSSMS) creates a common slot across all comb bars K into which control lever I pivots counter-clockwise. Its lower horizontal arm moves forward into the cranked end of link L, allowing the link to rise (leaf spring beneath) so that its projection moves into the path of lever M as it is driven clockwise by cam N. The subsequent right-to-left movement of link L rotates frame O and turns withdrawal lever P counter-clockwise. A pin Q, carried on lever P, depresses both pawls E, so releasing the type carriage which is then returned to the beginning of the line by spring T. The rotation of lever P brings its peg S under the latch on the inside of frame R, so ensuring that the pawls E cannot re-engage the rack while the carriage is in transit. When the carriage reaches the beginning of the line, projection H turns frame R counter-clockwise, releasing peg S, and so allows the twin pawls E to re-engage. Depression of the "MAN CAR RET" key simulates the selection of function control bar 1, by pushing link L to the rear manually, so operating frame O and lever P as described above.

7.5 Case Shift Mechanism (Fig 2.122)

Since the majority of the type bar slugs carry both "letters" and "figures" characters, the type bar segment A, **Fig 2.122**, must be able to take up two positions: "up" to print "letters" and "down" to print "figures and symbols". The vertical position of segment A is determined by tube B (itself part of shift beam assembly C) along which the segment runs, maintaining contact by means of a roller above the tube, and a plate below it. At the left-hand end of casting C is fixed an inverted Y-shaped arm which runs on a shift cam D fixed to a gear wheel E that meshes with quadrant F. **Fig 2.122** shows the shift mechanism in the "letters" position, ie segment A raised. If a "figure shift" code (MMSMM) is now received, the "figures" function control bar H is selected and rotates counter-clockwise, so moving the step on its lower vertical arm away from the projection on function bar 1 (black) which then moves down into the path of power bail J. The subsequent movement of bail J draws function bar 1 to the rear, and so turns quadrant F counter-clockwise, rotating gear E and cam D to lower bar B and consequently typebar segment A. Segment A is maintained in its new position when function control lever H resets at the end of the cycle, by jockey plate G. Selection of the "letters" function draws bar L on to power bail J. Subsequent movement of bail J turns quadrant F clockwise to raise rod B and segment A to the "letters" position. Code combinations that have a printing character in one case, and a machine function in the other, eg Who Are You? must have their function control levers (similar to H and K) blocked so that they do not select in "letters". This is done by shift bar S, which is moved to the left for "letters" and to the right for "figures" by cam M, operated through linkage N by an arm O clamped to spindle P that rotates with casting C. This shift bar S lies at the rear of the five code comb bars (shown at H on **Fig 2.119**). Bellcrank Q conveys this mark/space setting on bar S to link R in the Link Unit for the benefit of the tape punch unit described in paragraph 12.

7.6 Line Feed Operation (Fig 2.123)

The selection of the line feed function control lever A, **Fig 2.123**, in response to an incoming line feed code allows function bar B to be lowered into the path of the power bail C and so driven to the rear by cam D. The subsequent counter-clockwise motion of rod E draws link F downwards. A pin at the top end of link F pivots frame G (black) counter-clockwise causing feed pawl H, carried on the other side of frame G, to feed ratchet wheel I and hence platen J counter-clockwise by one line feed. The extent of the rotary movement conveyed to platen J by feed pawl H is determined by the manual setting on the line feed change lever K which can align the pin at the top of link F with one of the three

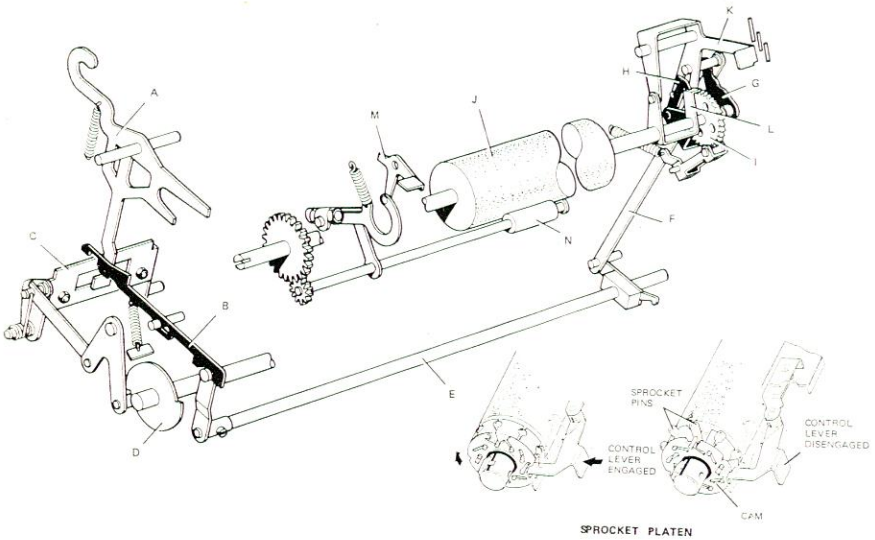


Fig 2.123. Line feed action.

notches in frame G; these notches (reading high to low) correspond to line feeds of $\frac{1}{6}$in, $\frac{1}{4}$in and $\frac{1}{3}$in respectively. Change lever K also determines the position of masking lever L against which feed pawl H rests when not operating (this feature enables the platen to be turned both clockwise and counter-clockwise without difficulty) and consequently the point at which the feed pawl engages the ratchet when it makes its downward movement.

7.7 Paper

Paper is normally held against platen J by pressure roller N. Depression of manual release lever M swings the spindle of roller N away from the platen so enabling paper to be threaded easily.

7.8 Sprocket Platen (Fig 2.123)

This platen though basically similar to the standard unit is equipped with retractable sprocket pins equally spaced around the circumference at the two extreme ends of the platen. Retraction is obtained by two independently controlled cams which can be held stationary while the platen is rotated. Right angled extensions to the sprocket pins pass through slots cut in the respective cam. The slots are angled towards the centre and when the platen is moved in relation to the cam the sprocket pins are withdrawn. The cams are locked by manually controlled levers which engage in vee's cut in the cams external circumference.

8. TWO-COLOUR PRINTING FACILITY

8.1 General (Fig 2.124)

The standard Model 444 machine has a mechanism, shown in **Fig 2.124** for varying the height to which the ribbon jumper rises when transmitting and receiving. This mechanism, coupled with the use of a two-colour ribbon, enables the operator to distinguish between messages originating from the local keyboard and tape reader (generally printed in red) and messages received from the distant station (generally printed in black).

8.2 Operation (Fig 2.124)

When the machine is at rest, ribbon jumper H is held down below the printing line by a pin 4 (inset) that links the twin arms F, and lies beneath projection 1 (inset) of the jumper arm bail D. As the type bail C moves forward to print, bail D follows, its upper angled projection 1 (inset) lifting the ribbon jumper H carried on arms F and stop arm G; all tied together by the pivot of roller E and pin 4 (inset) When the machine is receiving, bail J is positioned as shown permitting maximum lift, before the lower level of stop arm G touches bail J, so arresting jumper H with the black portion of the ribbon aligned with the printing line.

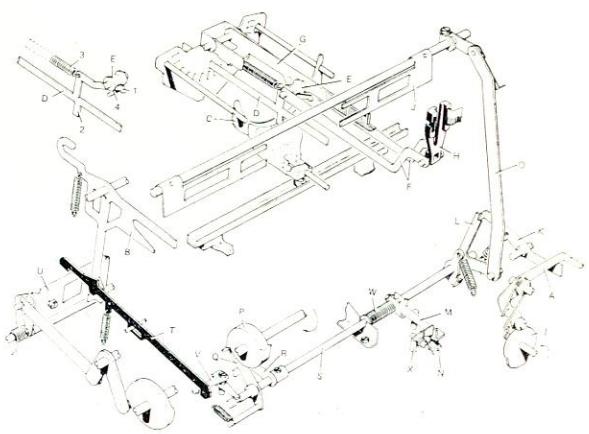


Fig 2.124. Ribbon lift, two-colour printing and answer-back trip actions.

8.3 When any transmitting key is operated, cam 1 on the transmitting cam sleeve rotates lever A which treads on trip lever K, so lifting its rear end out of a step in lever L. Lever L then rotates clockwise under spring action until stop arm M touches top screw N. This motion of lever L draws link O downwards and turns bail J inwards so that it lies vertically above the projection at the end of jumper stop arm G. The subsequent upward movement of jumper H is thus arrested at a lower level than before, and so brings the "red" portion of the ribbon to the printing line. The mechanism is reset to black at the end of every printing cycle by cam P on the main cam sleeve. This cam rotates lever Q which pivots around shaft S, counter-clockwise. Lever R, fixed to shaft S, is spring-loaded against the back lever Q. The consequent counter-clockwise motion of shaft S rotates lever L so that trip lever K can fall into its step again to set up the "black print" condition.

8.4 Answer-back Condition (Fig 2.124)

Shaft S is also capable of a lateral movement which is used to convey the answer-back trip action to the transmitter. When the Who Are You? function control lever B is selected, function bar T (black) is lowered into the path of power bail U, which then moves towards the rear. The subsequent clockwise motion of bellcrank V draws shaft S to the left against compression spring W. Arm M then slides trip pawl X (part of transmitter) to the left to initiate an Answer Back cycle.

9. RIBBON UNIT

9.1 General (Fig 2.125)

Fig **2.125** shows the two-way ribbon drive and feed changeover mechanism. Ribbon spools S1 and S2 are connected to their respective drive plates by a peg that passes through an off-centre hole in the spool. Ribbon tension is maintained by arms A1 and A2 which are spring-loaded away from the jumper, and to their lower ends are anchored one end of clutch bands P1 and P2. These bands pass round the drum part of ratchets H1 and H2 and are anchored at the other end to the retention pawl pivots. Springs joining these two anchor points urge them together, but when the ribbon tightens, the light pull on tension lever A1 or A2 slackens the grip of its associated band and allows the spindle and spool to rotate. The purpose of these band clutches is to prevent over-running of the spool from which ribbon is being unwound; this would otherwise cause a slack loop that may become entangled with the type bars.

9.2 Feed Action (Fig 2.125)

In the illustration, **Fig 2.125**, the left-hand spool and its vertical shaft are free to unwind since the associated feed pawl G1 and retention pawl J1 are held away from the ratchet wheel H1 by projections on the left-hand end of link K. Similar projections on the right-hand end of link K are displaced so far to the left that the right-hand spool's feed and retention pawls G2 and J2 engage the teeth of ratchet wheel H2. During the printing action, type bail B moves to the rear, rotating feed levers C1 and C2 and so moving their associated links D1 and D2 towards the front of the machine. Bellcranks pivoting around spindles F1 and F2 cause whichever of the feed pawls G1 and G2 is in contact with its ratchet, (G2 in this case) to move round to take up another tooth. When bail B restores after printing, the rearward movement of links D1 and D2 causes the engaged feed pawl (G2) to rotate its ratchet one tooth; the movement being retained by its associated retention pawl (J2). The movement of the displaced feed pawl (G1) is ineffective.

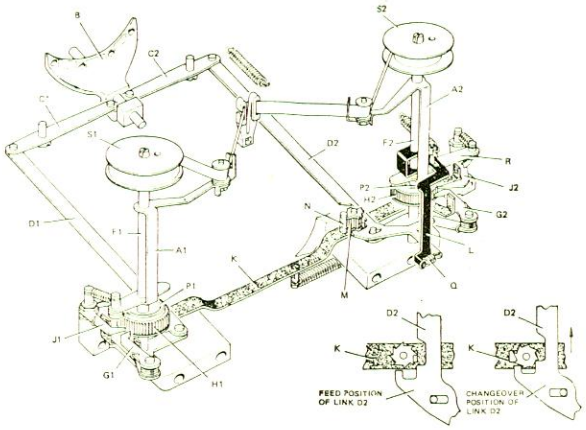


Fig 2.125. Ribbon feed mechanism.

9.3 Changeover Action (Fig 2.125)

Link K, which determines which of the feed and retention pawls will be in contact with their ratchet, is tensioned to the right by a spring. Its position is determined by a pin N tensioned against a star wheel M whose pivot passes through a slot in the link, and into the casting beneath. When the star wheel is rotated by the ratchet wheel beneath it to a position where the pin is presented to a recess between the arms of the star wheel, link K will move to the right, displacing pawls G2 and J2, and allowing pawls G1 and J1 to engage their ratchet wheel.

When all the ribbon has been transferred from one spool to the other, the full spool, in continuing to feed, will draw the ribbon tighter and tighter, so turning arm A2 clockwise, a pin on its lower arm R rotates changeover lever L, so moving its lower arm to the left and extending spring Q. The other end of spring Q draws link D2 to the left so that a cut-out in its left-hand edge, which normally misses the ratchet beneath star wheel M, is now in line with the ratchet. The next rearward movement of link D2 will cause the cut-out to engage the ratchet (see inset diagrams on **Fig 2.125**) and turn it an eighth of a revolution; the left-hand projection on link D2 acting as an overshoot stop for the ratchet. This movement of the ratchet and star wheel M causes link K to move to its alternative position, and so transfer the drive from the full spool to the empty one.

10. AUTOMATIC MOTOR SWITCH

10.1 General (Fig 2.126)

This mechanism, an optional extra on Model 444, is illustrated in **Fig 2.126**. It automatically switches off the motor power approximately 70s (50 baud working) after the end of the last message, and will switch it on again when there is an incoming message, or the local operator presses the "letters" key.

10.2 "Switch Off" Action: No Signal Incoming

Cam C, part of the continuously rotating main cam sleeve drive ratchet, acting through lever D, causes pawl lever assembly E to feed ratchet wheel I round one tooth; feed being retained by pawl L. Since ratchet I is larger than ratchet J, and the two feed pawls G and H are pinned together in line, for nine feeds out of ten the movements of assembly E do not affect the smaller ratchet J. Every tenth tooth of the ratchet is however, deeper than the others, so when pawl G passes into one of these, pawl H can move down far enough to feed its ratchet wheel J one tooth. Ratchet wheel J consequently rotates in the same direction as wheel I, but much more slowly; ultimately after about 70s, a stud on ratchet wheel J picks up a projection on link plate M, and slides the plate to the rear to set the motor on-off switch stud X to "off".

10.3 Motor running: Signals Incoming, or Keyboard Being Operated

When the receiver is operating, cam B on the main cam sleeve is rotating, so turning pawl release lever R clockwise. Arm R2 is thus lifted once each half-cycle, so disengaging the twin feed pawls G and H, and the twin retention pawls K and L from their respective ratchet wheels. The feed movement of assembly E is thus made ineffective while signals are incoming.

10.4 "Switch On" by Operation of "Letters" Key

Depression of "letters" key T, via linkages U, V, W and X, turns trip lever Q counter-clockwise, so releasing trip plate P which swings to the rear under the action of spring Y, using the right-hand end of lever O as a fixed pivot. The centre section of plate P acts on the shoe R1 of lever R, pivoting the lever clockwise. Extention R2 lifts the feed and retention pawls out of their ratchets, and allows plate M, which has been holding the motor switch at "off", to be moved forward by spring Z. As plate M moves forward, it acts on the right-angled lower extension S1 of lever S, turning the lever counter-clockwise. Extension S2 now turns plate P clockwise around lever O so that the right-hand end of plate P can re-engage the latch surface of lever Q.

10.5 "Switch On" by Incoming Signal

Consider the motor to be switched off, with stud J pressing link plate M to the rear, and the right-hand end of plate P latched on lever Q. The electromagnet armature N is at "mark" and lever O is resting on top of it. On receipt of a "start" signal, armature N moves to "space", ie to the right, so withdrawing support for lever O. Plate P then swings clockwise around lever Q as a pivot. The centre section of plate P acts on lever R1 pivoting it clockwise so that extension R2 can disengage the feed and retention pawls of both ratchets J and I. Link plate M now restores towards the front of the machine, allowing the motor switch operating stud X to move to "on", and simultaneously turning lever O counter-clockwise so that its long, horizontal arm moves back on to the top of armature N.

11. ANSWER-BACK FACILITY

11.1 General (Fig 2.127)

The drum of the transmitter unit answer-back mechanism can be coded to carry up to 20 pre-set characters or func-

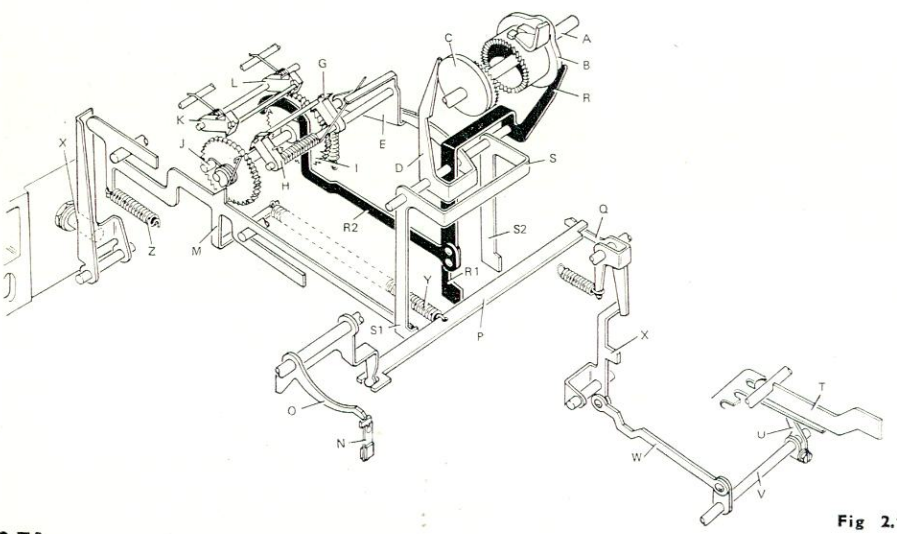


Fig 2.126. Automatic motor switch.

tions, usually the machine's station identification. Receipt of the "Who Are You?" enquiry (MSSMS) triggers this mechanism which then rotates a coded drum in front of the sequential levers (item U, **Fig 2.127**) simulating the action of the keyboard comb bar selecting levers to generate the required sequence of five-unit code signals, and send it to line. The answer-back mechanism can also be triggered locally by operating the "here is" key. Measures are taken to prevent the operation of the local "WRU?" key from releasing the local answer-back mechanism via the "local record".

NOTE: The following points regarding the construction of the latch assembly (items X, C, A, B and J) at the rear of the transmitter unit should be noted before reading the "sequence of operation" that follows. Trip pawl X is spring-loaded clockwise around rod H carried on frame A, and rests on arm J1. Frame A is free to run around rod D, but is sprung to stop-lever B, itself clamped to rod D. The pivot of lever J and catch C is fixed. Latch C is tensioned clockwise; its left-hand end normally rests against the underside of rod H.

11.2 Release of Answer-back Mechanism by Incoming "WRU?" Signal (Fig 2.127)

(*a*) Trip action: As described in paragraph 8, **Fig 2.124**, the receipt of a WRU? signal causes release arm M, **Fig 2.127**, to be drawn to the left. The consequent pressure on trip pawl X causes frame A, stop lever B, and shaft D to rotate together in a counter-clockwise direction until the vertical arm of lever B touches the casting; any further movement of arm M then extends the torsion spring linking frame A to lever B. Lever E, clamped to the front end of shaft D, rotates drum detent lever F clockwise, so lifting arm F1 out of the cut-out in disc O, and at the same time causing the roller on arm F2 to tread on lock lever N, moving it down far enough to engage clutch AG. The vertical arm of lever N is thus moved to the right, simultaneously displacing trip lever P to release clutch detent Q and rotating lock bail S clockwise. The lower surface of bail S thus moves all the selecting levers T clear of the ends of their sequential levers U, and in so doing prevents any keyboard operations from interfering with the answer-back transmission (see Part 2, Section B).

(*b*) Maintenance of trip condition: Until the end of the first cycle of cam sleeve R, this "trip" condition is maintained (after arm M is restored) by latch C which, as frame A moved down, was able to turn clockwise to wedge its left-hand end against the inside edge of rod H, so holding frame A in the "operated" position. As cam sleeve R starts to revolve feed cam Y turns lever Z counter-clockwise so feeding ratchet AC one tooth counter-clockwise. This movement simultaneously presents the first line of teeth on ward drum AD (teeth entire for "space"; broken out for "mark") to the top ends of the five sequential levers U, and rotates disc O so that its cut-away moves away from arm F1.

(*c*) Read action: Further rotation of cam sleeve R causes sequential levers U to move forward in turn to sense the pattern of teeth across the ward drum; the "blocked" and "free" conditions they encounter control the common frame and the striker (items N and Q, **Fig 2.117**) to produce the required mark/space electrical conditions and convey them to line, as described in Section 2.

(*d*) Transfer of trip holdout: During the "stop" signal of the first answer-back character, the WRU? inhibition lever V turns counter-clockwise (selector lever AB being withdrawn by frame S), its left-hand extension treading on pin J2 to turn lever J momentarily counter-clockwise. This movement of lever J lifts arm J1 so that latch G can pass beneath it, and, simultaneously, urges latch C counter-clockwise to restore its left-hand end to the rest position beneath rod H. Frame A can now restore clockwise, so transferring the maintenance of the "detent trip" from latch C to arm F1 which moves down to run on the edge of disc O.

(*e*) The subsequent upward motion of release arm M (a by-product of the "reset in black" movement of shaft S, **Fig 2.124**, around which arm M is clamped) at the end of the main cam sleeve half-revolution, pivots latch G clockwise, so allowing lever J to restore to the rest position shown in **Fig 2.127**. The movement of inhibition lever V which raises arm J1 on to latch G at the end of each reading cycle, and the subsequent disengagement of latch G by arm M, is repeated for the remaining 19 characters, but is ineffective.

(*f*) Conclusion of transmission: The "feed and read" operation is repeated for the remaining characters on ward drum AD until the cut-out on disc O is presented to extension

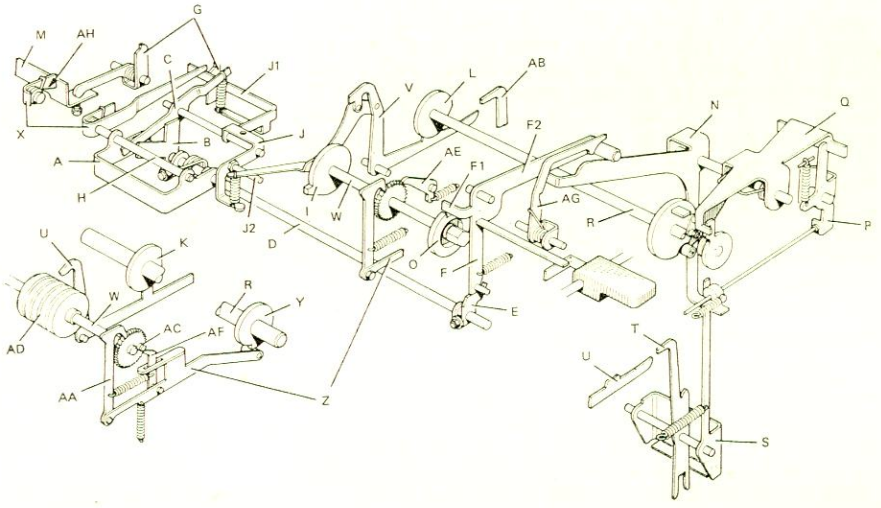


Fig 2.127. Answer-back operation.

F1 on the twentieth character. Lock lever N then restores to normal (the roller on the right-hand end of the horizontal arm of lever F displacing latch AG as it rises) allowing detent Q to arrest cam sleeve R, and frame S to move counter-clockwise away from selector levers T.

(*g*) Twenty-first feed: On conclusion of the answer-back transmission, it is necessary to rotate drum AD one more position to bring an "all blank" position opposite the reading ends of sequential levers U, so enabling control of these levers to pass back to the keyboard. This additional feed action is produced by the spring-loaded pawl AF which, during the twentieth "read off" cycle, is displaced by stud AC and then moves back beneath it, as lever Z moves clockwise to restore after the twentieth counter-clockwise feed operation, pawl AF pushes up on this stud, and so moves the ward drum round to the "all blank" position. This same movement of lever Z also raises feed pawl AA into the next tooth of the ratchet wheel ready for another answer-back operation.

11.3 Suppression of Local Answer-back Response when "WRU" Code is Transmitted (Fig 2.127)

(*a*) General: It is necessary to prevent the local answer-back mechanism from being activated via the "local record" when the local operator depresses his WRU? key to enquire the identity of a distant station, otherwise both the "local" and "distant" answer-backs would be released simultaneously. This double operation is prevented by breaking into the trip linkage from release arm M to shaft D, so making the right-to-left movement of arm M ineffective.

(*b*) Keyboard components: The mechanism that produces this effect is controlled initially by the WRU? key on the keyboard. Comb bar O, **Fig 2.116** (at the rear of the comb bar assembly) is normally depressed by the operation of any key other than the WRU? key, so maintaining link P to the right; depression of the WRU? key D, however, engages the single tooth on comb bar N and depresses it to slide link P to the left.

(*c*) Suppression action: The right-hand end of link P, **Fig 2.116**, controls a special selector lever which appears at AB on **Fig 2.127**. This lever is normally hooked over the tail of inhibition lever V, except when the WRU? key is operated; in this instance lever AB then moves away to permit lever V to follow its cam. When the "stop" signal of the WRU? enquiry is being transmitted to line, lever V turns counter-clockwise. Its left-hand extension treads on pin J2, raising arm J1 on to latch G. In so doing, arm J1 pivots pawl X counter-clockwise so that the subsequent movement of arm M to the left (in response to the "local record" interpretation of the transmitted WRU? signal) is ineffective, as the arm passes into cut-out AH. At the end of the main cam sleeve cycle, the "reset to black" movement of arm M pivots latch G clockwise to restore pawl X to its normal position.

11.4 "Here Is" Action (Fig 2.127)

The local answer-back can be brought into operation by a manually-operated "Here Is" key located above the teleprinter keyboard. Operation of this key simulates the movement of lever E by turning drum detent F clockwise via a direct mechanical link to the rear of the key assembly; thereafter the mechanism operates as described above.

12. TAPE PUNCH UNIT

12.1 General (Figs 2.128 and 2.129)

The tape punch unit and its associated drive arm is mounted on the left-hand side of the machine, within the cover. The unit produces fully-punched five-track paper tape at the maximum speed of the associated teleprinter, and feeds this tape out towards the operator from beneath a V-shaped tear-off face. The unit is controlled from the receiver link unit described in paragraph 6.5. It therefore records received messages directly, and transmitted messages indirectly via the electrical "local record" path. Code combinations are punched in the same cycle as they are printed. Provision is made for automatic suppression of the punch and tape feed actions on up to four codes, which can be in either or both shifts. Two of these codes are usually "J Bell" and WRU?; the other two can be used for mechanical control of the PERF ON and PERF OFF keys. These ON and OFF keys can also be controlled remotely via electromagnets. When required, the "suppression" mechanism can be inhibited, and all 32 code combinations punched.

NOTE: The following points regarding the construction of the tape punching, tape feed, and on/off control mechanisms shown in **Figs 2.128** and **2.129** should be noted before reading the description which follows:

(*a*) **Fig 2.128**: Items E, H and G all pivot freely around spindle F. Clutch drive boss E (black) has a single dog which fits into the rear end of the L-shaped slot in clutch plate H. Cam plate G (black) has two similar dogs which fit into the other end of this slot, one on each side of spindle F. To expose clutch plate H, cam plate G has been exploded to the left. Drive arm C and reset arm Q are both clamped to spindle D; drive casting B pivots around spindle W. The on/off key assembly has been moved forward to expose the drive boss and cam plate (shown in black); on/off roller M, carried on frame J, has therefore been shown twice. The "entire" leader line from letter M shows the true position of this roller. Frame J pivots around spindle L. The horizontal slot in link O, through which pin P2 passes, permits the

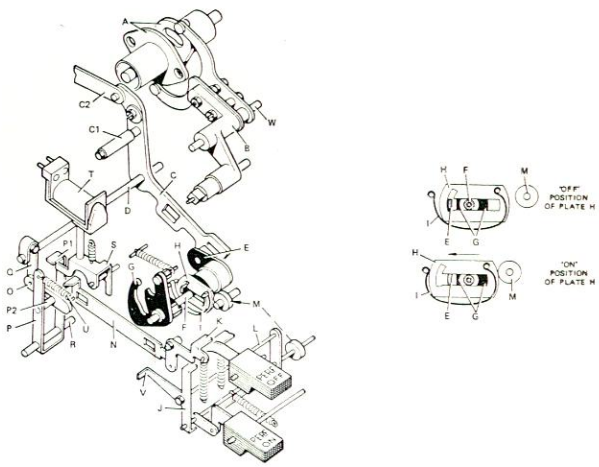


Fig 2.128. Tape punch on/off control and drive mechanism.

link and its arm Q to follow the rocking motion of drive arm C without disturbing latch lever P (which pivots around spindle R), whose face P1 is normally held against latch S by spring U.

(*b*) **Fig 2.129**: Cam plate G provides power for two actions; punching, and tape feed. As these actions are separated in the illustration, plate G has been shown twice. The roller at the top of plate G moves in a curved slot in drive plate L, fixed to punch operating frame K; for clarity, plates G and L have been exploded to the left.

12.2 Drive for Punch and Feed Actions (Figs 2.128 and 2.129)

Through drive casting B, **Fig 2.128**, the twin cams A on the receiver main cam sleeve impart a continuous rocking motion to drive arm C. The top rear end of arm C carries a horizontal roller C1 that controls the code reading levers (A, **Fig 2.129**) and a link C2 that operates the punch suppression lever reset frame (C3, **Fig 2.129**). The front end of arm C connects with a trunnion block which converts this rocking motion into rotary motion of boss E (black) around spindle F. Boss E has a dog which fits into the L-shaped slot in clutch plate H. In the OFF position, plate H is urged towards the front of the machine by leaf spring I so that this dog simply moves up and down in the vertical part of the slot without conveying its motion to clutch plate H or cam plate G, whose dogs lie in the horizontal part of the slot. Depression of the ON key turns frame J clockwise around pivot L, so causing roller M to push clutch plate H towards the rear, where it is held by the action of latch K on the top arm of frame J. This movement of plate H brings the dog of boss E into the horizontal part of the slot in plate H (as shown in the inset) where it joins the two dogs of cam plate G. Plate G is thus temporarily linked to boss E, and so takes up its rocking motion. The roller at the top of cam plate G provides power for the punching action; the vertical slot generates the tape feed action. Both these actions are illustrated in **Fig 2.129**.

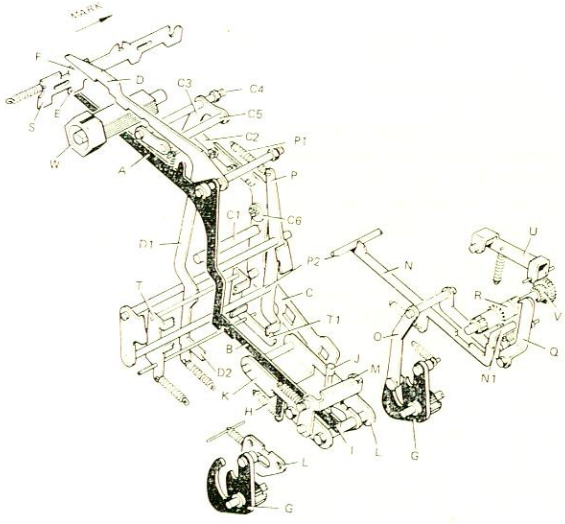


Fig 2.129. Punch control and tape feed actions.

12.3 "Off" Action; "Manual" and "Remote" (Fig 2.128)

(*a*) Manual: Operation of the OFF key lifts latch K, **Fig 2.128**, to release frame J and allow roller M to withdraw from clutch plate H. At the end of the cycle, plate H is moved towards the front of the machine by spring I, so bringing its vertical slot into line with the dog on boss E, where the subsequent up and down movement of the dog is ineffective. Plate G is thus brought to rest.

(*b*) Remote: The unit can be switched off remotely by energizing relay T, **Fig 2.128**.

12.4 Operation of the ON key results in frame J turning clockwise and being retained by latch K. Link N is thus moved to the rear to bring it close to the vertical arm P1 of latch lever P, normally held against latch S by spring U. Because of the horizontal slot in link O, latch lever P is not disturbed by the to and fro movement of the link arising from the rocking motion produced in arm Q by drive arm C. When relay T is energized, latch S is depressed (by the vertical rod) below face P1, so allowing frame P to follow the next forward movement of link O. Arm P1, drawn by spring U, engages the rear vertical surface of link N, and moves the link towards the front of the machine, so upsetting latch K. The consequent counter-clockwise motion of frame J withdraws roller M, so breaking the link between boss F and plate G to bring the punch to rest.

12.5 Punch Selection Actions (Fig 2.129)

(*a*) Code hole punches: The pattern of holes that will be punched through the tape for a particular code combination is determined by the lateral positioning of the five "active" links (one shown at S, **Fig 2.129**) in the link unit, whose lower projections are sensed by the five code reading levers A, **Fig 2.129**, which control punch anvils B. The projections along the top edge of links S are similarly sensed by up to four punching suppression levers, of which D is typical.

(*b*) Operation: At the point in the reception cycle when the code is about to be passed from the selector unit to the link unit, the front end of drive arm C moves down. Sleeve C1, carried on arm C, urges the code reading lever A away from projection E; linkage C2 turns frame C3 counter-clockwise; to lift roller C5 and hence suppression lever D away from projections F. Links S are now free to accept the new code setting. Once the new code is established on links S, drive arm C turns counter-clockwise, withdrawing sleeve C1 to allow code reading bars A to rise and sense projections E. Links that have been set to the right for "mark" allow bars A to pass up the left-hand side of projections E; punch anvil bars B, which are tensioned by spring H against the retreating lower end of reading levers A thus move the rear to bring projection I beneath the associated punch J. A subsequent upward movement of punch operating frame K, which carries the five code punches J and the feed hole punch, produced by the action of the roller of cam plate G in plate L (part of frame K), causes a hole to be punched in the tape for this particular code element. When punch operating frame K is lowered again, withdrawal frame M pulls any "marking" punches out of the paper. Links S that remain at rest in the "space" position (as shown in **Fig 2.129**) leave their projections E in the path of the rising reading levers A, and so prevent the associated anvil bars B from moving to the rear.

The cut-out to the rear of projections I on anvil bars B thus remains beneath the punches, which are not therefore affected when frame K is raised.

12.6 Feed Hole Punching and Tape Feed Action (Fig 2.129)

The feed hole punch anvil bar N, **Fig 2.129**, which is carried in frame K along with the five code hole punch anvil bars, is normally tensioned to the rear against bar P2 in suppression frame P. In this position the entire part of bar N lies beneath the feed hole punch, so that when frame K is raised, a feed hole is produced in the tape. As cam plate G turns clockwise to lift frame K, its internal cam track turns feed lever O counter-clockwise so lifting feed pawl Q into the next tooth of ratchet wheel assembly R, which also carries the tape feed pin wheel. The downward movement of pawl Q, produced when cam plate G restores, rotates assembly R one tooth, so drawing a further $\frac{1}{10}$in of tape through the die assembly.

12.7 Punch and Feed Suppression

For some applications it is a requirement that the codes for "Who Are You?" and "J Bell" should not appear in the perforated tape. To provide for this requirement, up to four punch suppression levers (such as D, **Fig 2.129**) can be fitted. These levers operate as follows:

(*a*) As the front end of drive arm C rises, roller C5 on frame C3 lowers suppression levers D to sense projections F. If the code is a "normal" one, levers D will each be blocked by at least one projection F. When a code that requires to be suppressed is set up on links S, however, a gap will open across all five links, and the selected lever D will move down into it. (A sixth link, shown at R on **Fig 2.122** and operated from the case shift control mechanism (paragraph 7.5) enables levers D to discriminate between codes such as "D/Who Are You" which are "normal" in the "letters" shift, but require to be suppressed in the "figures" shift).

(*b*) The subsequent counter-clockwise motion of the selected lever D causes its face D1 to pivot latch frame T clockwise, so disengaging its latch T1 from the lower arm of suppression frame P. Urged by spring P1, frame P now turns counter-clockwise; rod P2 pushes the lower ends of any "marking" code reading levers A forward to the "space" position. Rod P2 also moves the feed hole anvil bar N forward so that its cut-out lies beneath the feed hole punch; extension N1 displaces tape feed pawl Q. The next upward movement of punch operating frame K will therefore be ineffective as the code and feed hole punch anvils have all been set to "space" and feed pawl Q has been displaced, so effectively suppressing the code established on links S.

(*c*) When drive arm C subsequently turns clockwise to lower the punch operating frame, eccentric roller C6 rotates suppression-frame P so that it can re-engage latch T1 and so restore control of the anvil bars B to reading levers A.

12.8 Punch ON/OFF on Receipt of Selected Code (Fig 2.129)

A special depression lever, similar to D, **Fig 2.129**, can be fitted which, when selected, causes its face D2 to push link N, **Fig 2.128**, forward, releasing latch K and frame J to bring the punch unit to rest. Face D1 on this lever suppresses the "off" code by acting on rod P2 in the manner described above. Another suppression lever can be used to operate linkages that act on extension V of frame J, Fig 2.128, to simulate depression of the ON key.

12.9 Tape Loading (Fig 2.129)

Depression of the TAPE RLSE key raises retention arm U, **Fig 2.129**, and the pressure roller that holds the tape down on to assembly R, to enable the tape to be threaded easily over the pin wheel.

12.10 Back Space (Fig 2.129)

The first part of the "back space" key movement disengages pawl Q, **Fig 2.129**, from the ratchet wheel assembly R, and engages a "back feed" pawl with reverse ratchet V. Further movement causes this "back feed" pawl to turn assembly R counter-clockwise by one tooth. Retention arm U maintains the pin wheel and the tape in its new position.

12.11 Suppression Control Knob (Fig 2.129)

The punch suppression action of levers D, **Fig 2.129**, is inhibited in one position of control knob W, **Fig 2.129**. This knob has two other positions, one which suppresses upper case D(WRU) and J(Bell), the other is used when the suppression mechanism is being adjusted. These three settings are indicated by 1, 2 and 3 stripes respectively on three adjacent faces of the hexagonal knob, and correspond to the following conditions:

(*a*) One stripe to top: This is the "normal" position, as shown in **Fig 2.129**. All code reading levers A and suppression levers D are free to operate; upper case (D(WRU?) and J(Bell) are suppressed so do not appear in the tape.

(*b*) Two stripes to top: This setting blocks the movement of all the code reading levers A and the suppression levers D; it is only used when the suppression mechanism is being adjusted. If the punch is switched on with the control knob in this position, only feed holes will be punched in the tape.

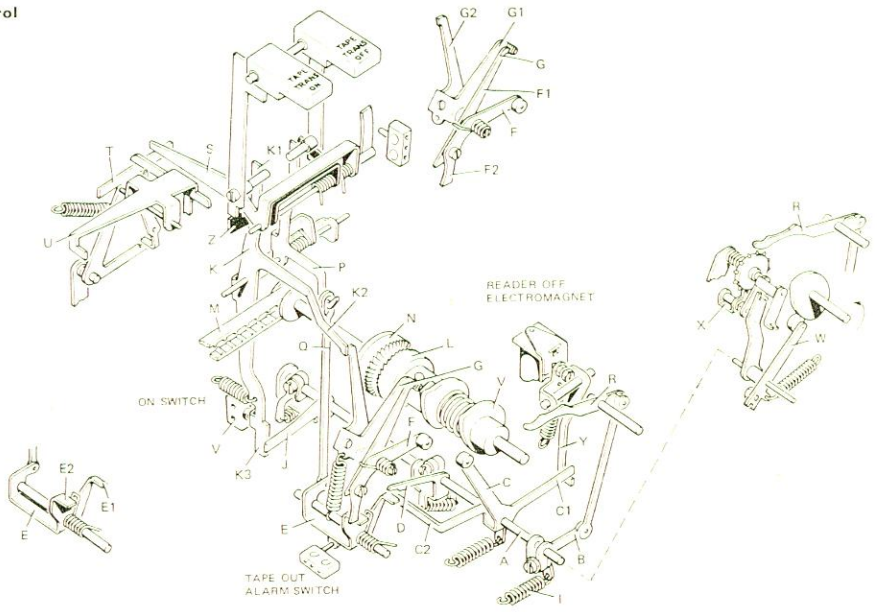
(*c*) Three stripes to top: In this setting, the suppression levers D are blocked, but the code reading levers are allowed to operate normally. All received code combinations, including "Bell" and "WRU?" are therefore recorded on the tape.

13. TAPE READER UNIT

13.1 General (Fig 2.130)

The tape reader unit, which is located at the right-hand side of the keyboard panel, will read five-track, $\frac{11}{16}$in fully-punched or chadless tape at the maximum speed of the associated teleprinter. The unit has its own striker transmitter of identical design to the one employed in the keyboard transmitter and answer-back unit (paragraph 5), but uses the send/receive switch of the keyboard transmitter.

Fig 2.130. Tape reader on/off control and read and feed actions.



13.2 Two manually-operated keys, labelled TAPE TRANS ON, and TAPE TRANS OFF, control the reader mechanism, which is illustrated in **Fig 2.130**. The "tape out" and "tape gate open" conditions bring this mechanism to rest automatically, and signal the condition to the controlling equipment by an "alarm" microswitch. Another microswitch indicates when the reader is ON. The reader can be brought to rest remotely by energizing a "Reader off" electromagnet.

NOTE: The following points regarding the illustration concerning this unit should be noted before reading the "sequence of operation" given below.

Fig 2.130. Shaft A is tensioned clockwise by a spring I; for convenience this is shown on lever B, although it is actually located on lever J. Lever B is clamped to shaft A; lever C pivots around this shaft; lever D can turn around the shaft, but is tensioned counter-clockwise against a block clamped to the shaft; lever J can also turn around this shaft, and is tensioned clockwise against a block clamped to the shaft. Detent reset lever assembly F is urged counter-clockwise by spring O.

13.3 Rest Condition (Fig 2.130)

Fig 2.130 shows the reader mechanism in the rest condition, with both control keys at "normal". Arm G1 of detent G is holding clutch assembly L and N open, being maintained in this position by arm K2 interposing on arm G2. Arm J is raised to block any counter-clockwise motion of trip lever K, so holding the ON key inoperative. Clutch driving member N is being driven continuously counter-clockwise by belt M from the transmitter drive shaft.

13.4 Loading Tape (Fig 2.130)

When tape is loaded and the tape gate latched down, the "tape out" lever R, **Fig 2.130**, is depressed, so rotating shaft A counter-clockwise. This movement urges latch D down on to face 1 of lever E, and moves arm J down clear of start trip lever face K3.

13.5 Starting Procedure (Fig 2.130)

Operator depresses the OFF key, then the ON key. A horizontal pin on the OFF key lever turns stop reset lever P counter-clockwise, lifting link Q to rotate stop lever E counter-clockwise. Arm E1 now latches on arm D, and face E2 is thus held down clear of the lower end (F2) of lever F. Lever F now turns counter-clockwise; detent G is still held on extension K2. When the ON key is depressed, a similar horizontal pin depresses arm S to tread on Z-lever T, so upsetting the trip linkage from the keyboard to the keyboard transmitter detent U. The same pin turns lever K counter-clockwise; arm K3 operates the "on" microswitch, arm K2 releases detent G which lifts to allow ratchet clutch L to engage its drive N.

13.6 These actions are repeated for the third, fourth and fifth code elements; the position of peckers G dictating whether a "mark" or a "space" will be transmitted. When the fifth element sequential lever E has restored, the cam sleeve holds all levers E (including the "start" lever) down, allowing plate F to turn counter-clockwise and move carrier I to the left. The last upward movement of lever J and striker K then sets the dolly to connect negative "mark" polarity to line for the "stop" signal.

13.7 Tape Feed Action (Fig 2.130)

A fork in the rear arm of lever W, **Fig 2.130**, enfolds a pin carried on feed pawl assembly X, which pivots freely around the pin wheel spindle. During the "stop" signal, feed cam lever W is turned clockwise by its cam, so urging the feed

pawl assembly to the right. The nose of the feed pawl works directly into the pins of the pin wheel, which acts as a ratchet, and feeds the wheel round $\frac{1}{10}$in each cycle. The pin wheel is retained by a friction clutch around its pivot, when the pawl moves back (during the "start" signal of the next cycle) to take up the next pin.

13.8 Continuous Transmission (Fig 2.130)

During the fifth code element, a detent reset cam acts on the horizontal arm of lever F, **Fig 2.130**, turning it clockwise. This action causes arm F1 to press detent G1 momentarily down into the path stop surface on clutch L. The reset cam, however, falls away and allows detent face G1 to rise again before the stop surface on clutch L reaches it. The clutch therefore runs through, and transmission continues until one of three circumstances arises:

(*a*) The reader senses "tape out", or the tape gate is opened

(*b*) the operator presses the TAPE TRANS OFF key

(*c*) the external equipment energizes the "stop" magnet.

13.9 Stop Action on "Tape Out" (Fig 2.130)

Under "continuous transmission" conditions, stop lever E, **Fig 2.130**, is latched against arm D; face E2 is thus held down out of the path of detent lever F. When a "tape out" or "gate open" condition occurs, arm R and consequently shaft A are turned clockwise by spring I. This same movement lifts arm D to release stop lever E, which is then turned clockwise by its torsion spring to bring face E2 up against the tail of lever F. (If this condition occurs later in the cycle, face E may pass up the inside of face F2.) When detent reset lever F is subsequently turned clockwise by its cam (against the tension of the spring on detent G) face E2 moves up to block the counter-clockwise motion that would otherwise occur as the detent reset cam falls away. Detent face G1 thus remains in the path of clutch member L, which is then pressed back out of engagement with drive member N to bring the mechanism to rest in the "alarm" condition. The operator then presses the OFF key to restore the mechanism to normal.

13.10 Stop Action when "Off" Key is Operated

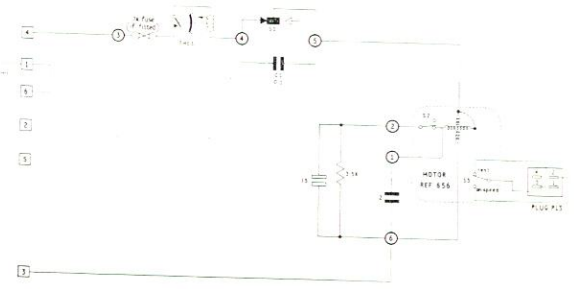
Assume that the reader is running continuously with the tape gate down, so that stop lever E is latched on arm D; the ON key is held depressed by latch lever Z, and arm K2 is held up clear of detent arm G2. Once each cycle, reset lever F pushes detent G1 down into the path of the clutch, but allows it to rise again before the clutch stop surface can reach it. If the operator now presses the OFF key, latch lever Z (black) is lowered to release the ON key and consequently lever K, which then tries to turn clockwise under the action of the spring on its lower vertical arm. Depending on the instant in the cycle at which the OFF key is operated, arm K2 will now either rest on the top of arm G2, or pass down the left-hand side of it. In either case, the next time detent face G1 is moved down into the path of clutch L by lever F, it will not be allowed to rise again because arm K2 will have blocked the path of arm G2. The mechanism is thus brought to rest again.

13.11 Remote Control Stop Action (Fig 2.130)

When the stop magnet is energized from some external source, lever Y, **Fig 2.130**, withdraws the support for arm C1 of magnet lever C, allowing the lever to follow its cam V which ultimately turns it clockwise. Arm C2 lifts arm D, so freeing stop lever E which then turns clockwise to bring the mechanism to rest as described above. Cam V then relatches arm C1 on to lever Y ready for the next remote stop action. In common with the "Tape Out" stop action, this is an "alarm" condition which is reset to normal by the operator depressing the OFF key.

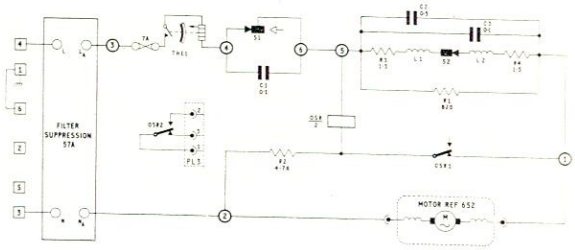
13.12 End of Cycle (Fig 2.130)

When the cam sleeve comes to rest on detent G, **Fig 2.130**, at the end of a transmission, the operator will press the OFF key. This action lifts extension S to free the keyboard transmitter, and allows trip lever K to turn clockwise. Extension K2 blocks detent G; extension K3 is blocked by arm J when the tape is removed; the rest of the mechanism then returns to the state illustrated in **Fig 2.130**.



SYNCHRONOUS MOTOR CIRCUIT

□ connections on 6-way motor unit power plug
S1 automatic motor switch
S2 'start' capacitor contacts
THE1 manually-reset motor overload contacts
○ motor unit 6-way tag block
S3 'on speed' contacts
PL3 'on speed' wiring plug



A.C. GOVERNED MOTOR CIRCUIT

□ connections on 6-way motor unit power plug
S1 automatic motor switch
S2 centrifugal governor contacts
○ motor unit 6-way tag block
ORS 'on speed' relay
R1 governing resistor
THE1* manually-reset overload contacts
PL3 'on speed' wiring plug

*for 160V d.c. governed motor, delete THE1 and substitute 850mA 'anti-surge' fuse.

Fig 2.131. Creed Model 444 motor wiring.

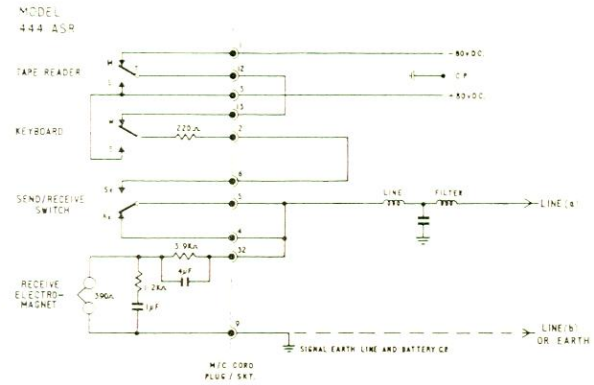


Fig 2.132. External circuit, double current, simplex.

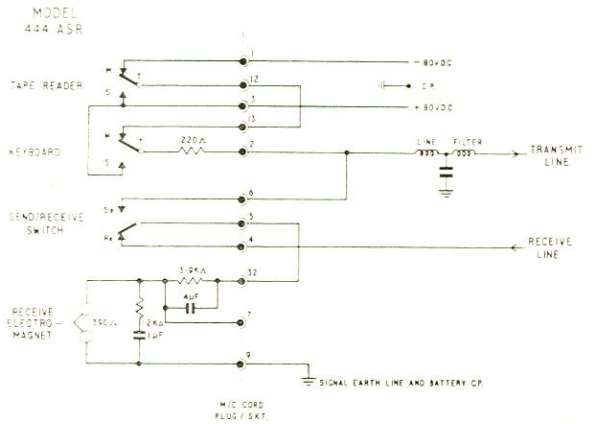


Fig 2.133. External circuit, double current, half duplex.

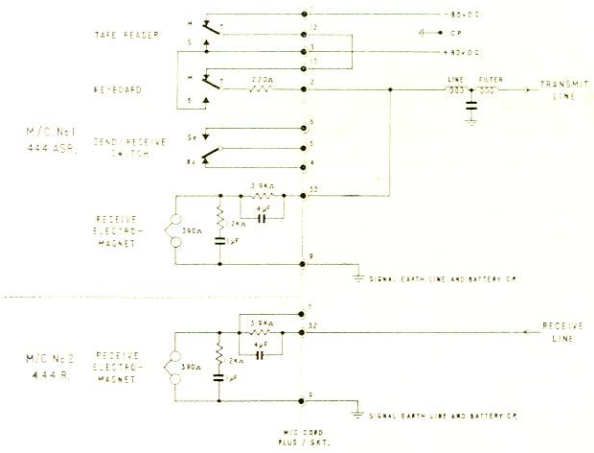


Fig 2.134. External circuit, double current, full duplex.

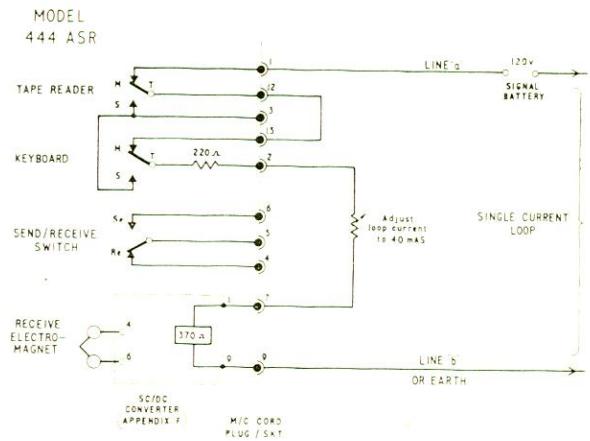


Fig 2.135. External circuit, single current, loop.

CREED MODEL 444
Electrical circuit detail

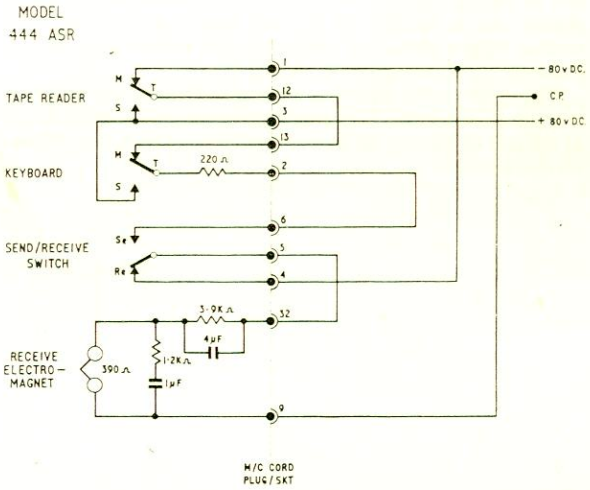


Fig 2.136. External circuit, local operation.

TELETYPE MODEL 15

General

The Model 15 teleprinter, manufactured by the Teletype Corporation of Chicago, is probably the most widely used teleprinter by radio amateurs throughout the world. The military versions are the Signal Corps TG7—A and TG7—B.

The Model 15 was supplied either as a transmit/receive model complete with keyboard or without keyboard as a receiving only (—RO) model. A Model 15 teletype may also be found with a perforating attachment fitted to the keyboard. In this case, the teleprinter has come from a Model 19 set. It should be noted that a standard Model 15 cover will not fit over a machine with a perforating attachment.

These machines come with a variety of motors, 60Hz synchronous, 115V dc, 50/60Hz and 25Hz ac governed motors.

Some Model 15 units are available with gears to enable running at 75wpm, 56 bauds, thus being partly compatible with the later Model 28 and 32 machines. Although 75wpm amateur operation is contemplated in the States, UK amateurs are not allowed to use other than 45 or 50 bauds and so must restrict themselves to the governed motors. The governed motors do have hash-filters built in but a 0·002 μF capacitor from each governor brush to earth makes a difference and a good earth connection between cover and base helps. This subject of hash-generation seems to be a very individual one and no two solutions are identical.

The governed motor speeds are adjusted by observing strobe marks on the governor through a vibrating fork. The forks are:

45 Bauds—Teletype Corporation No. 72634 or No. 103628 —87·6Hz.

50 Bauds—Teletype Corporation No. 104984, US Army Signal Corps. No. WT 104984, marked "British Speed, 404 opm,"—96·19Hz.

Receiving Mechanism

The Model 15 is a page printer. The paper roll remains stationary, while the type bars in a carriage are moved from left to right as the machine prints. The whole printing and typing unit is secured to the case base with four knurled screws. When these are removed, the whole unit can be removed for cleaning and servicing.

The input to the receiving section is through the red plug run out of the base. This connects to the polar relay found in the rear of most of the machines that have been in commercial hands.

The TG7—A and TG7—B do not have the Western Electric 255A polar relay fitted in the back of the machine; instead the magnets are operated directly from the loop current. As it is preferable to run the selector magnets directly from the loop, those machines with polar relays can be altered. See **Fig 2.137**.

The magnets on the receiving unit are fed from the polar relay section by means of slip-contacts on the base.

The magnets may be of two types:

(1) Pulling magnets, connected in series for a 60mA loop.

The older versions were equipped with a selector mechanism that operated by the magnets pulling an armature. This required a fair amount of force and hence the 60mA loop for correct operation.

(2) Holding magnets, connected in either series or parallel (determined by switch position), for 20mA or 60mA loop operation.

With these newer selectors it was arranged that the armature was moved by the motor up to the magnets and then released. If current flows through the magnets the armature is held, if no current flows then the armature falls away. Despite the 20mA facility, operation on 60mA is recommended in amateur operation due to loop time constant considerations and the fact that most rtty demodulators are designed to drive 60mA selectors.

Identification of the type of selector is straightforward. With power disconnected from the motor and magnets, turn the machine over by hand. With holding type selectors the armature can be seen to be presented mechanically to the magnets—with the pulling magnets the armature does not move.

Since only 20 per cent of each code unit is actually required by the selecting mechanism, it is most desirable to set, or "orient", this selecting interval in the middle of each code unit. This is set by means of the "range-finder" which moves the selecting interval with respect to time by varying the position of the latch assembly. This determines the start point where the mechanism begins to move after the electrical start pulse is received. This start point can be moved over a period of time greater than that of a 22ms code pulse, thus allowing for slight speed variation between sending and receiving machines.

When no signal is being received the selector mechanism, driven through a friction clutch, is stopped from rotating by the stop arm on the driver shaft pushing against the stop lever on the orientation unit.

Reception of a start pulse (a no current condition) releases the armature, depressing the trip plunger on the

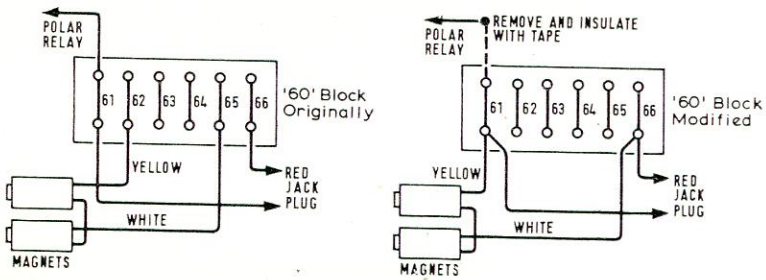


Fig 2.137. Teletype Model 15 selector magnet wiring modification.

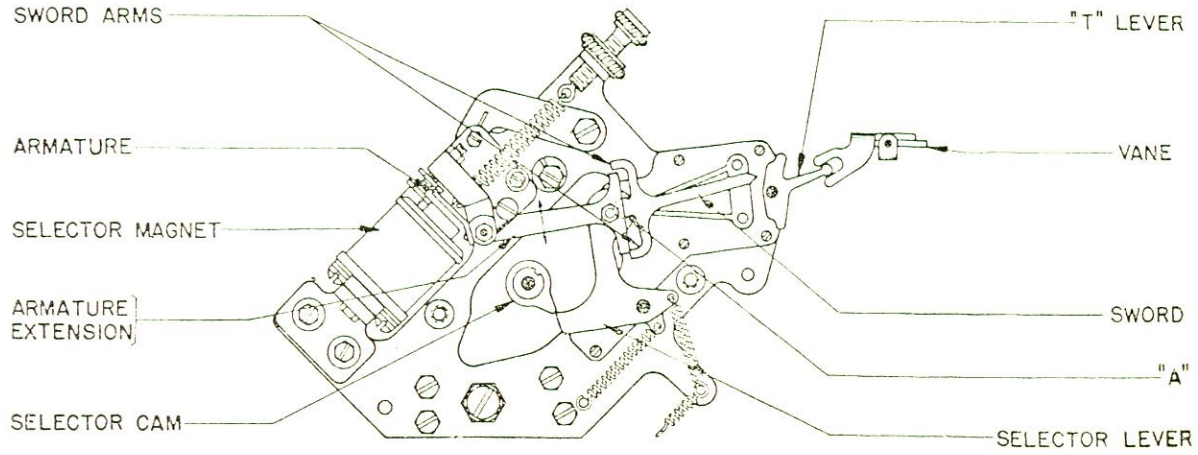


Fig 2.138. Model 15 selector mechanism.

orientation unit and, through the trip latch, throws the stop lever out of the way causing the selector cams to rotate.

Suppose that the next code unit is a mark (a current "on" condition) causing the armature to hold in. The cam rotates the selector lever, **Fig 2.138**, anti-clockwise about A pulling with it the sword which strikes the upper end of the armature extension. The sword then rotates clockwise about B and on further rotation of the cam projection the selector lever springs back pushing the sword on to the lower end of the T-lever. This causes the front edge of the vane to move downwards bringing with it the bellcrank and thus sliding the code bar to the left. See **Fig 2.139**.

On receipt of a space the selector magnet and its armature extension are then in their unoperated positions. Hence the sword, when pulled back by cam rotation, strikes the lower end of the armature extension, swivels and engages the upper half of the T-lever, moving the forward edge of the vane upwards.

The five code bars are held in the type basket and are slotted corresponding to the code. For any combination of the five signal elements the slots in the combination bar are aligned so that only the pull-bar corresponding to the code received can drop down. This is then engaged by the pull bar bail as it is moved forward by the motor, causing the type bar to fly up and print the character. See **Fig 2.140**.

The function bars are found immediately behind the vanes. They are slotted in such a way that they will only move forward into the vanes when the position of the vanes corresponds to the desired character. For example, on receipt of "Fig S" the "Fig S" function bar will be allowed by the vanes to move forward; this raises the extension lever from the bell into the path of the motor operated bail reset bar. This gives a momentary impulse to the extension lever, causing the bell to ring.

Another facility found on these machines is the "downshift on space" facility. This causes a machine in upper case to drop down into lower case when a space is received. This facility can be switched in or out by means of a little lever. This lever is positioned about the middle of the function bar comb and towards the forward edge. It is about 2in long and tightened with a screwdriver. Looking at it from the front of the machine it sticks out between the vanes and the top of

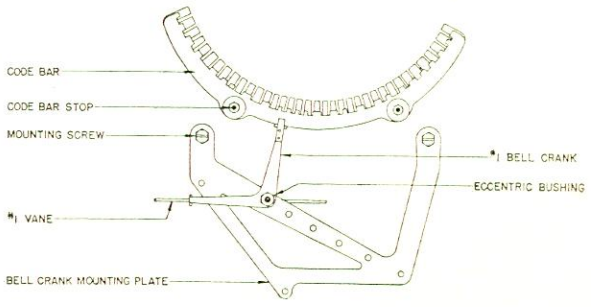


Fig 2.139. Model 15 bell crank system.

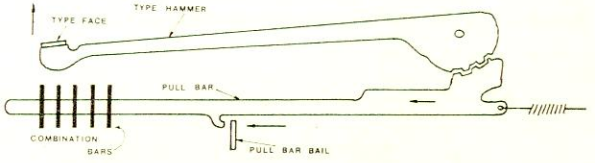


Fig 2.140. Typehammer mechanism.

the keyboard casting. It should be swung over to the left and tightened up again. The automatic "downshift on space" is a very useful function indeed when printing on QRM'd bands.

The carriage is operated by gearing from the selector shaft. When a character is received a clutch is thrown in to cause the vertical carriage drive shaft to move round a few degrees at a time through a ratchet. This rotary motion is transferred to the carriage assembly by means of a rack and pinion type assembly. When a character is received that does not require a carriage advance (eg LF, letters, figures, etc) a throw out is

operated by the function bars to prevent the carriage drive clutch from engaging. As the carriage moves along the rails from left to right a spring inside a casing below and behind the platen is wound up by means of a strong fabric tape attached to the carriage. On receipt of the "carriage return" signal the ratchet is released and the carriage is pulled back to the left hand side of the receiving unit by the spring. If the machine is being run at tape speeds the speed of return of the carriage to the start of the new line is sometimes longer than it takes to receive the "line feed" signal which results in the character at the start of the next line being printed in the middle of the page. The only way to prevent this is to send two CRs at the end of each line—which should be done anyway in amateur rtty working to minimize errors at receiving end.

The Transmitting Mechanism

This consists of a keyboard and the mechanical linkage to the selector drive shaft, all mounted as a plug in unit to slide into the main base casting.

There are two types of keyboard:

(1) Standard.

(2) Fitted with perforator. The only difference between this and the standard one is that the keyboard code bars are extended to the left of the main casting to position the punches.

The keyboard code bars are slotted identically to the receiving code bars on the type basket. Depression of a key causes the code bars to move to the left or right according to the character. See **Fig 2.141**.

The transmitting cams have their indentations arranged so that the mark and space intervals are of the correct length and occur at the correct time.

Situated above the cams is the transmitting hash filter and on the model with the perforator there are a set of contacts running off another cam for operating the punch magnets when in the "Kybd and Tape" position. Behind the transmitting contacts are the operation switches on the keyboard model, while to the left of the transmitting contacts is the polar neutral switch. This is for operating the polar relay off either a neutral or polar line. Since it has been recommended that the receiving magnets be operated directly from the line and the polar relay dispensed with, this push-pull switch is redundant.

At the left hand side of the keyboard is the send-receive break switch. Its function depends on the type of interconnecting circuitry in use in the amateur station. At some stations the magnets and keyboard are wired in series. The machine is usually operated with the switch in the "send" position. Thus, when a key is pressed, even when the machine is receiving, the loop is broken—this is to facilitate break in working. In the "receive" position the receiving mechanism works normally but the keyboard is isolated. In the "break" position the loop is broken, ie a continuous "space" is sent. This facility was included for machines with the "figs H" motor stop function. This allowed any machine to turn off the motors of any other receiving machines by sending the "figs H" or "stop". The start pulse or any space signal would turn on the motors again. This feature is nothing but a nuisance in amateur rtty operation and should be electrically and mechanically disconnected.

When putting the machine into operation a normal typewriter ribbon may be used. To enable the ribbon-reverse mechanism to operate a pair of eyelets should be fastened about 4in from each end of the ribbon to engage the ribbon-reversal levers.

DISASSEMBLING THE PAGE PRINTER INTO ITS MAIN UNITS

Instructions for Removing the Keyboard Unit

Loosen the thumb screws and draw the keyboard unit out to the front.

Instructions for Removing the Type Bar Carriage

Operate the carriage return lock bar and move the type bar carriage with the right hand to its extreme right position. Lock the carriage in place by pulling the dashpot lever to the left and the margin adjusting screw arm to the rear so that the right margin adjusting screw just clears the lever. Hold the carriage return spring drum with the left hand, unhook the draw strap with the right hand and hook it on to the margin bell hammer spring post. Operate the carriage return

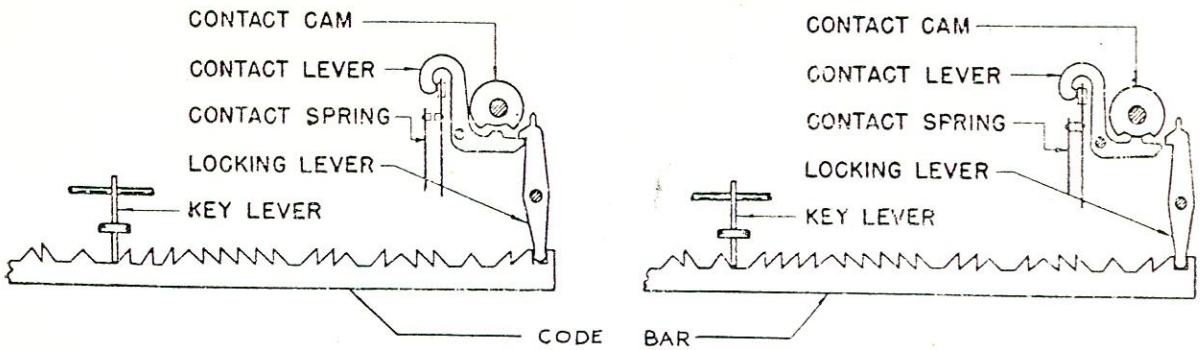


Fig 2.141. Transmitter mechanism.

lock bar again and remove the carriage by sliding it off to the right.

Replacing the Type Bar Carriage on the Typing Unit

1. Shift the platen to the "figures" position (up) and press the carriage return lock bar for an instant.
2. Move the printing bail to its rearmost position.
3. Hold the carriage in the right hand.
4. Turn the right margin adjusting screw arm to the rear, but do not turn by full 90 degrees as otherwise it will strike the frame.
5. Push the pull bar bail roller with the right thumb to the rear so that the roller slides on to the printing bail tracker.
6. Rest the type bar carriage on the carriage track, making sure that the guide screw engages the slot in the carriage track.
7. Engage with the left hand Nos. 1, 2, 3, 4 and 5 vanes, one after the other in their respective bellcranks.
8. Move the type bar carriage to the middle of the carriage track.
9. Move the right margin adjusting screw arm to its vertical position.
10. Move the type bar carriage to its extreme right position

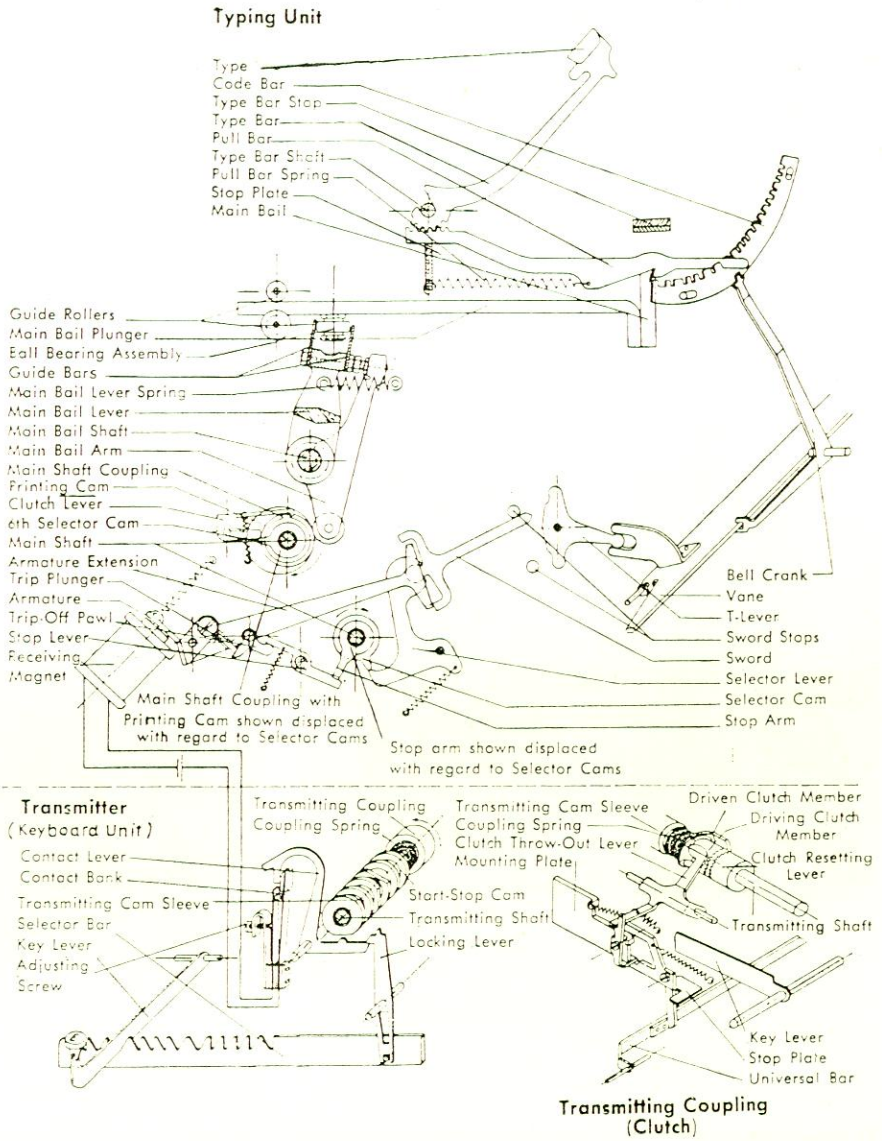
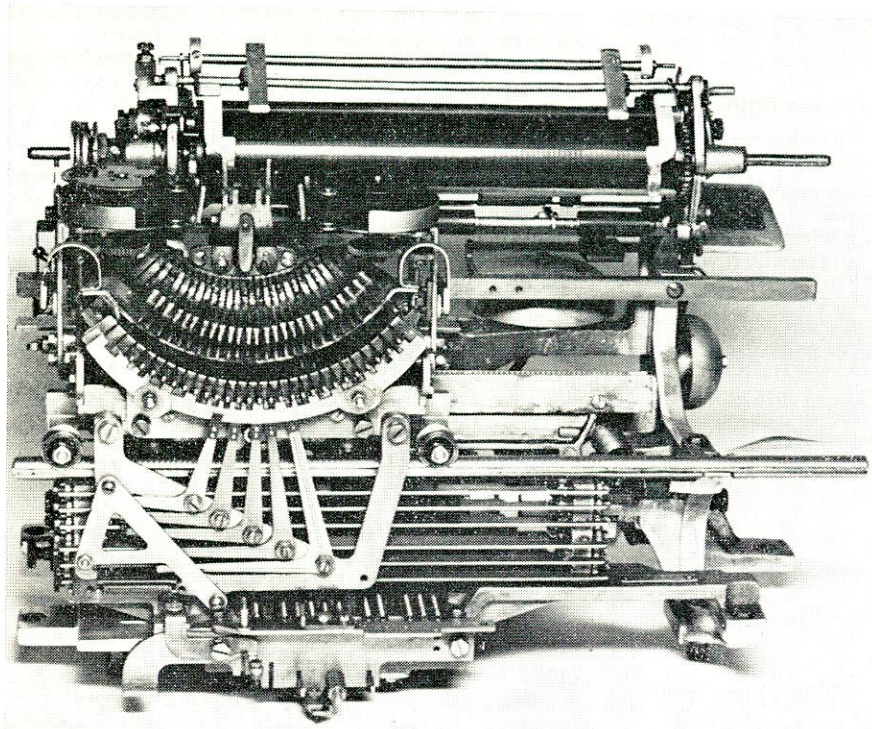
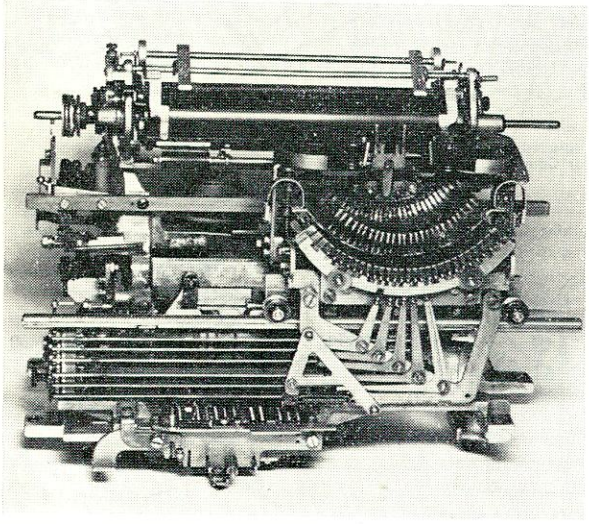


Fig 2.142. Teletype 15, transmitting, selecting and printing process perspective diagram.

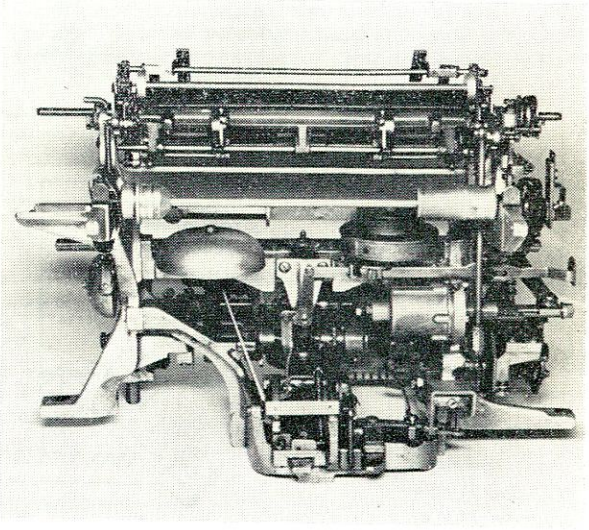


Teletype 15 typing unit removed from base, with type basket at extreme left-hand side.

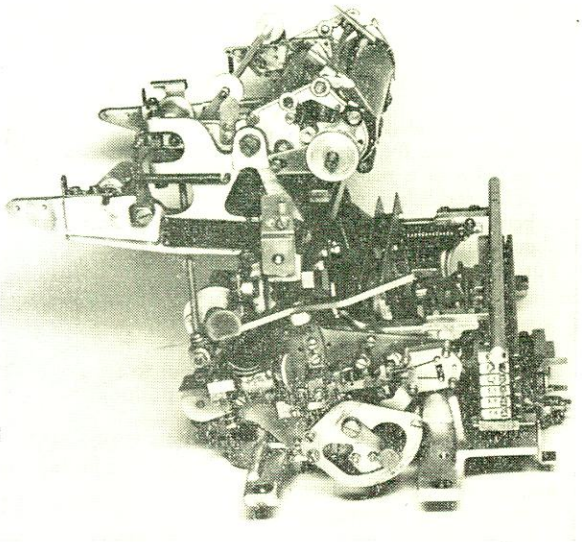
THE TELETYPE MODEL 15: DETAIL



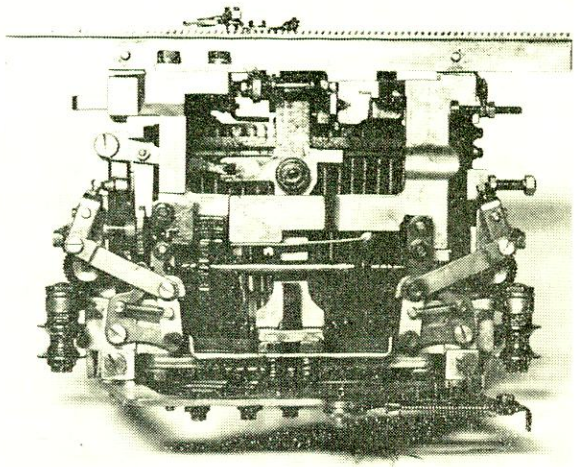
Teletype 15 typing unit removed from base assembly, with basket at extreme right-hand side.



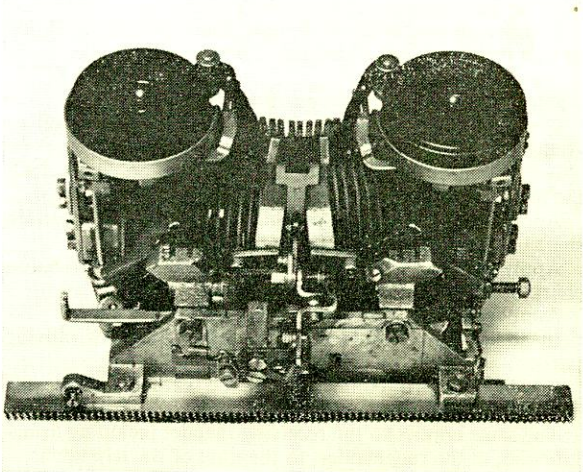
Teletype 15 typing unit, rear view. The two bells are end-of-line and signal.



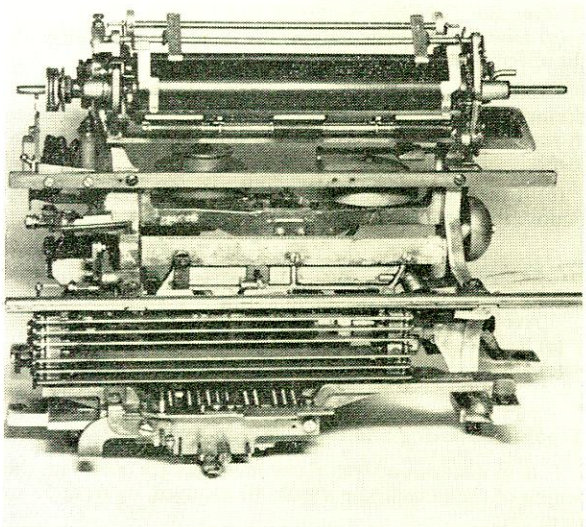
Teletype 15 typing unit, type basket removed.



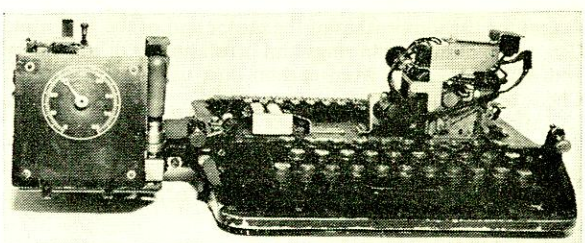
Teletype 15 type basket underside.



Model 15 type basket showing letter-feed rack.



Teletype 15 typing unit, type basket removed. The vanes are the six horizontal bars in the front lower part of the illustration.



The Model 15 keyboard with character counter and perforator as fitted to the Model 19 composite set. See p 2.94.

and lock it in place by pushing the dashpot lever outward to the left.

11. Hold the carriage return spring drum so that the spring cannot unwind and hook the eyelet of the draw strap over its mounting post on the carriage.

12. Operate the carriage return lock bar to permit the carriage to return to its initial position.

Instructions for Removing the Typing Unit

Loosen the three thumb screws and the cylinder head screw and remove the typing unit. Now the page printer is disassembled into its four main units.

MAINTENANCE AND SERVICING

Lubricants

The following code is used in the lubrication diagram for indicating the correct lubricant to be used on the various parts of the mechanism:

"Y" Thin oil: Shell-Paraffin-oil V8050
"B" Thick oil: Shell Talpa oil 30
"R" Grease: Shell FL—2

Maintenance and Servicing

(*a*) *After approximately 50 operating hours*

Remove all dust and ribbon residuals. Take care in doing so that the dust is not wiped into contacts or bearings.

(*b*) *After approximately 200 operating hours*

Clean the entire equipment from dust and excess oil or grease, clean the pallets.

Apply thin oil as indicated in the lubrication chart. Soak the four oil felts of the main shaft with oil.

Apply thin oil to the ball pressure oiler at end of the main shaft until it drops out of the main shaft.

Apply thick oil to the points indicated on the lubrication chart. Soak the oil felt of the transmitter.

Apply grease as indicated by the lubrication chart.

In addition apply thin oil to all other joints of moving parts.

CAUTION. All contacts must be carefully protected from oil or grease.

The same applies to the receiving magnet including armature and, at the rangefinder, to the nose of the trip latch.

No oil must find access to ball bearings.

Clean contacts by pulling through them in one direction with a strong, non-fibrous paper.

In the same manner clean the armature of the receiving magnet.

Test the carbon brushes of the motor and of the governor. Clean commutator, slip rings and brush holder of the motor and of the governor from carbon dust using a soft brush. Check on the motor speed.

Perform a functional test.

(*c*) *After approximately 3,000 hours*

Wash the machine with washing benzene, white spirit, etc (excepting the receiving magnet).

Inspect in detail all parts.

Check all adjustments of the equipment according to specification.

After the washing process dip the motor ball bearings and ball bearings of the main shaft into thin oil (Shell Paraffin oil V8050) let the oil drop off, and then fill the bearings with special ball bearing grease, Calypsol W1A.

Service the equipment as prescribed after 200 operating hours.

It is recommended that under normal operating conditions (eight hour day), the equipment be thoroughly cleaned and overhauled once a year. A general disassembling procedure cannot be established; in any case, the equipment should first be taken into four main units: typing unit, type bar carriage, keyboard unit and base.

Further disassembly:

I. Rangefinder removal (Receiver)

(*a*) Selector unit

Exactly observe the layout. Be careful to replace each shim in its former place and in its right position.

(*b*) Main shaft

Take main shaft apart, replace the felts if necessary.

Before reassembling saturate felts with oil until they no longer swim on the surface of the oil.

(*c*) Remove the printing bail

Replace rollers by needle bearings if possible, before replacing the printing bail, fill the bearing frame with grease.

(*d*) Remove the platen unit frame.

NOTE: If the receiver is disassembled as specified above, the main adjustments remain undisturbed but with the selector mechanism and rangefinder assembly to be readjusted. However, a check of all adjustments should be made in accordance with the instruction manual.

When the printer is disassembled into main units listed under (*a*) to (*d*) above easy accessibility is provided to all other parts.

Further disassembly should be avoided unless absolutely necessary.

II. Type Bar Carriage, Removing Bell Cranks

(*a*) Disassemble code bars in the manner as specified for the selector unit.

NOTE: Do not loosen the screws of the code bar base plate during this procedure. Be careful to replace the brass discs in such a way that the lubricating holes are in exact alignment.

(*b*) If the segment with the slots for the type is very dirty, remove the type bars.

III. Keyboard Unit

(*a*) Remove the selector bars.

Avoid loosening the screws of the two stop brackets.

(*b*) Remove the transmitting shaft with cam sleeve.

(*c*) Unscrew contact assembly for cleaning.

Trouble Shooting and Repairs

1. If mutilations of teleprinter messages are observed, the setting of the rangefinder should be changed, eg from 55 to 60 or 65.

In case of further mutilation the printer should be checked in the local circuit by means of a rectifier.

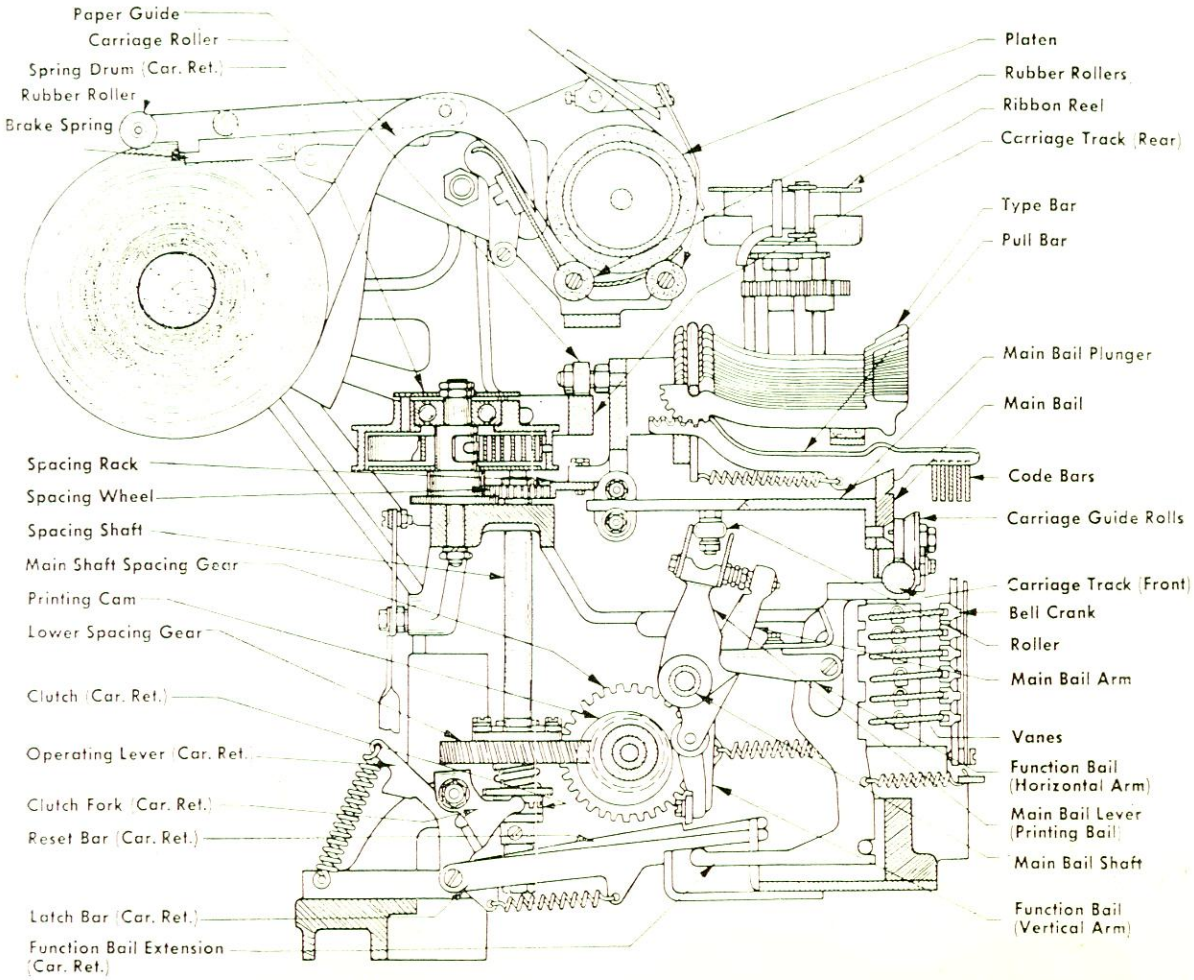


Fig 2.143. Model 15, schematic representation.

Having established that the defect lies in the printer, check:

(*a*) motor speed

(*b*) the adjustment of the rangefinder stop lever which should have no axial or radial play.

(*c*) the adjustment of the selector unit. There should be 0·4 and 0·7mm clearance between the sword peak and the stop pin.

(*d*) the overlapping

(*e*) the magnet clearance

(*f*) the locking wedge clearance

(*g*) the adjustment of the vanes (0·1 to 0·2mm clearance on both sides)

(*h*) the bell cranks adjustment (upper and lower rear edges of vanes must symmetrically engage the locking function lever)

(*i*) if code bars move freely.

2. Circuit open or shorted.

(*a*) Check whether there is line current and whether the line plug fits well into the socket.

(*b*) Check clearance between stop lever and trip latch. With the armature released, there should not be more than 0·05mm clearance.

3. Noise in motor operation.

(*a*) Check play between motor pinion and main shaft gear.

(*b*) Check motor pinion meshes with the middle of the helical gear.

GENERAL: If the letters or figures are not printed in a uniform height, the type bars must be readjusted. Never remove the type bar in question in order to adjust its position. Before

exchanging any type bar, remove the type bar carriage and the type bar guide by loosening the two cylinder head screws.

The position of the character "M" should be taken as a basis for any adjustment.

FUNCTIONAL TEST

Ribbon Adjustment

Switch on the printer. Depress individual keys and check whether the ribbon is fed upon depressing the keys. At the unrolling ribbon spool press the one ribbon lever and depress a key. The ribbon feed shaft should then snap into its alternative position.

Shifting

(*a*) Depress alternately the LTRS key and the FIGS key. In doing so test whether the platen frame is properly shifted.

(*b*) Depress the FIGS key and subsequently the BELL key. The bell should then sound.

(*c*) Depress the LTRS key, then the J-key. The J must be printed.

Rangefinder Adjustment

(*a*) *Testing the Range*

Connect the page printer and a transmitter distributor with a line current rectifier. Check the speed of both printer and TD motors. Adjust the line current to exactly 40mA.

By means of a TD send the message contents of a tape on which the letters RY have been punched alternately.

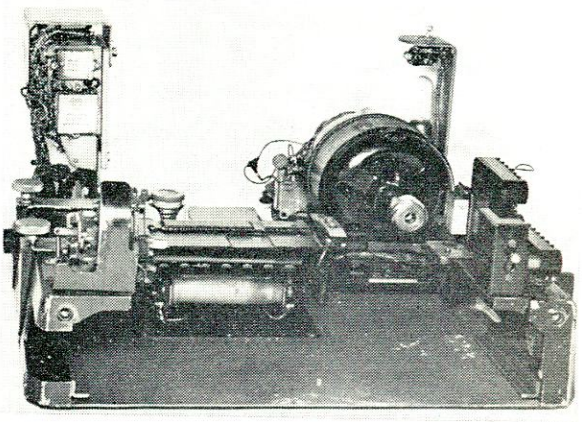
Loosen the wing nut or thumb screw at the rangefinder index arm and shift the index towards smaller degree figures until the equipment just ceases fault-free printing RY.

Read the setting of the index arm over the scale.

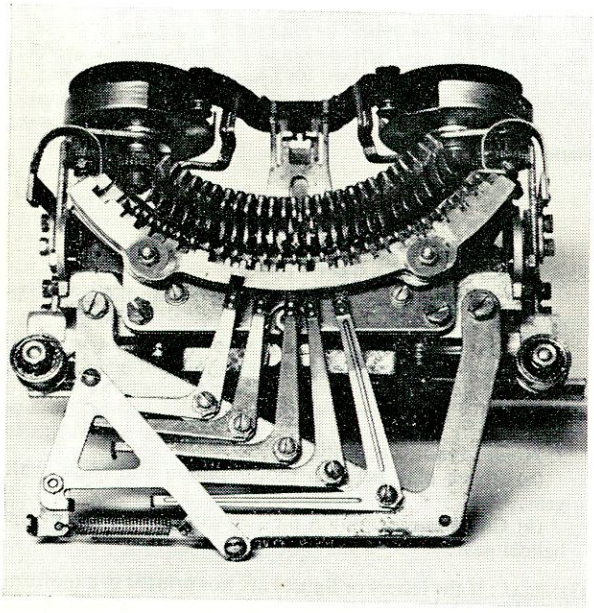
Then shift the index arm towards higher scale figures until the equipment again ceases fault-free printing of RY. Read the adjusted scale value.

If the difference of these two scale figures exceeds 80 degrees, then all adjustments are satisfactory.

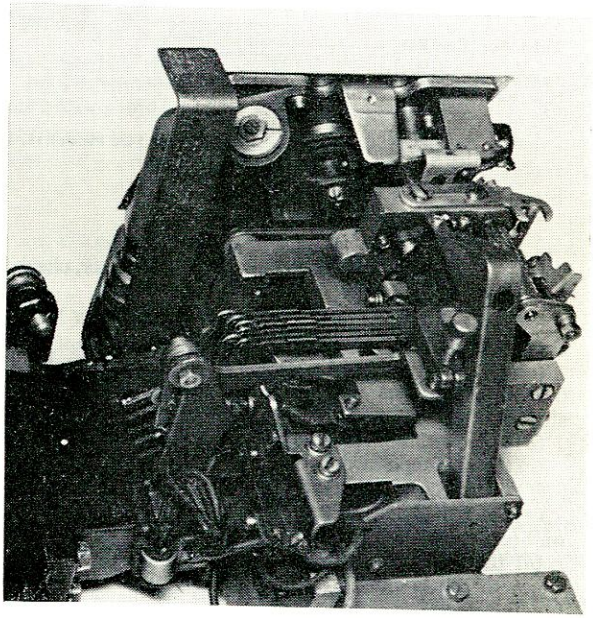
If the two scale values are approximately equidistant from the end of the scales set the rangefinder index to the centre value between the two mentioned scale figures. It will then be positioned within the range 55 to 65 degrees.



Model 15 base assembly. The lamp is used to illuminate the governor target when carrying out speed adjustments.

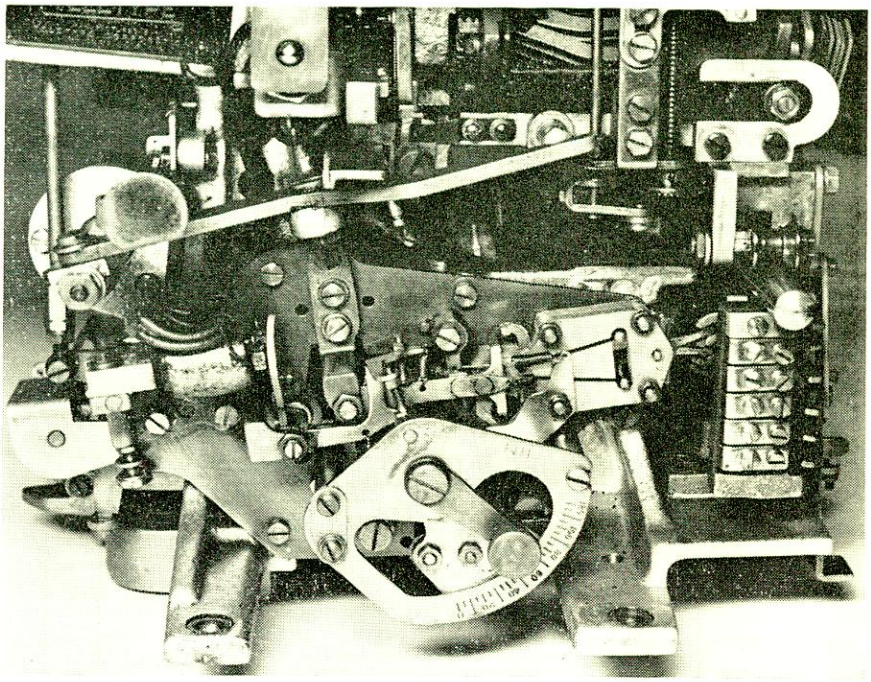


Teletype 15 type basket showing code bar bell-cranks.



Teletype 15, rear view of perforator showing punch operating bars.

Teletype 15 selector mechanism and range finder.

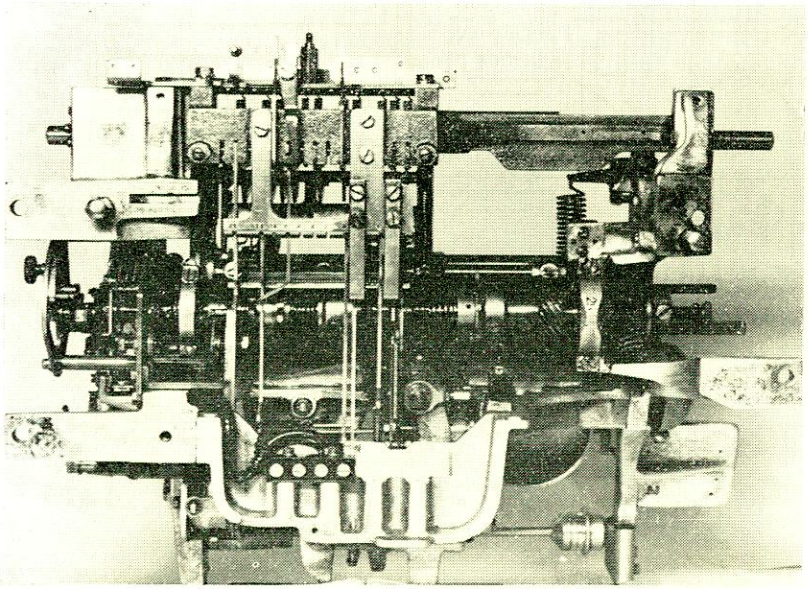


(b) Shifting of the Rangefinder range

If the two scale values read off during the above test are not nearly equidistant from the ends of the scale shift the rangefinder range towards higher or lower scale values by advancing or backing up the knurled screw. (If the range is orientated too far to the side of the higher values, for instance, advance the knurled screw.) The tension of the armature spring should remain in the range 5·3 to 7oz if possible, since otherwise the rangefinder range would become too narrow.

Further, the receiver magnet can be readjusted: for this purpose loosen the two screws.

If the rangefinder range is displaced towards the higher scale values, mount the receiving magnet nearer to the armature, so as to reduce the clearance between each magnet core and the armature down to 4mil (0·1mm).



Teletype 15 typing unit showing main shaft at the centre.

If the range is displaced too far towards the lower scale values, increase the clearance between the magnet cores and armature up to 8mil (0·2mm).

(c) Increasing the Range

If the range is smaller than 80 degrees, it may be improved by the following measures:

Loosen the screw at the armature extension and increase the clearance between the blade of the locking wedge and the edge of the locking lever up to 12mil (0·3mm). Moreover, try whether turning the locking wedge yields success.

If in spite of these measures the range cannot be extended beyond a width of 70 degrees, recheck the adjustments at the selector mechanism.

The Lorenz Company in Germany have manufactured quantities of the Teletype 15 under licence and designated them the Model LO15. These machines appear to be similar to the Teletype versions, but have metric screw threads. Some LO15s have governed motors, and are unusual in that they are equipped with four brushes, spaced at 90 degrees. Generally, the finish on the LO15s is extremely high and many are fitted with white keytops. Desk mounted versions in polished wood cabinets are quite common also.

Due to the similarity of the two makes of Model 15, the adjustments, etc apply to both, although the photographs used in the text are of both types, and detail differences may be seen between them.

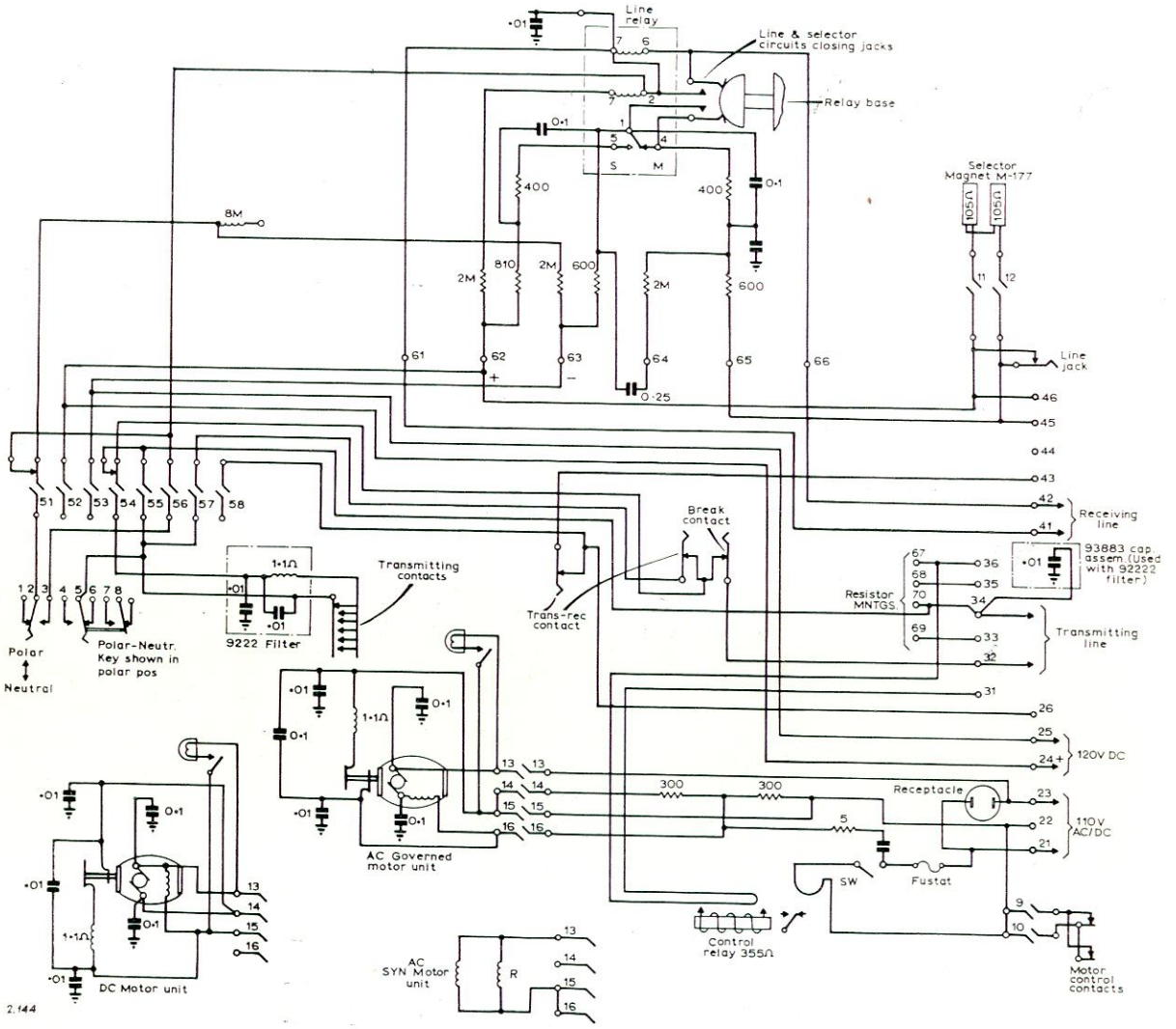
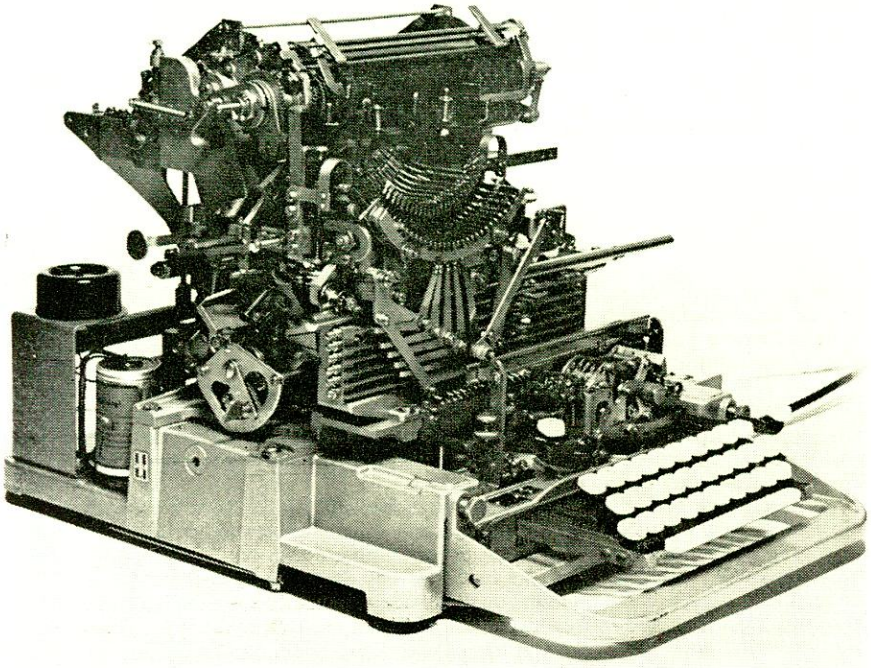


Fig 2.144. Model 15, wiring diagram.

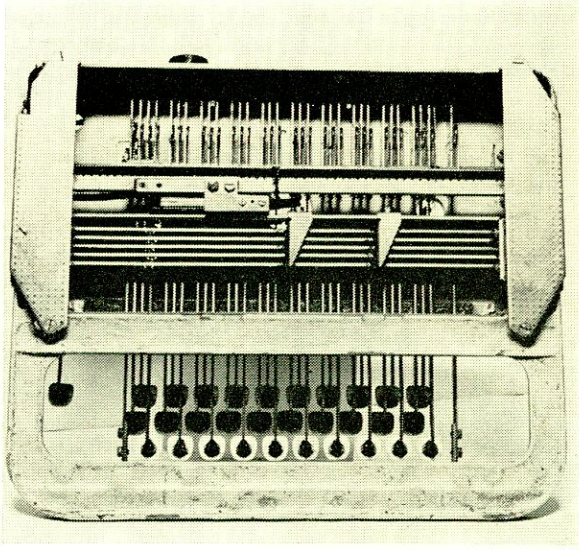


THE LORENZ VERSION OF THE TELETYPE 15

(Another view: p. 2.94)

The Lorenz LO15. This machine is very similar to the Teletype 15.

Teletype 15: Lorenz LO15 keyboard fitted with answer back.



The Lorenz LO15 keyboard, underside, as fitted to the Teletype 15.
See also p. 2.94.

MODEL 19 COMPOSITE UNIT

This Teletype unit consists of a Model 15 printer with a perforating keyboard and a Model 14 transmitter distributor (TD) mounted on a specially built table with all power supplies and switching built in. It is a very compact unit and means that an amateur rtty station with all the facilities required can be set up with the minimum of interconnecting cables. The whole unit weighs about 3cwt.

The various sub-units are all interconnected with polarized connectors. There are also facilities for attaching a reperforator. A circuit of the table connections and a diagram of the various terminal blocks is shown in **Fig 2.146**. The large two-position, four-pole knife switch selects ac power for the printer and TD motors from either the power supply or a 115V ac line supply. It is as well to check the voltage to the motor before actually connecting it as the wrong position of this switch would result in 240V ac mains being applied to the 115V motor.

The actual power supply may either be a saturable reactor type REC 6 or the later electronically regulated KS5988 or REC 30. The latter is most likely to be found in models obtainable in the UK. These have type 323A or 323B thyratrons. As these are expensive an emergency repair* if one goes weak (hazy blue colour instead of deep blue) or open filament, is to substitute a 200V 1A silicon rectifier for the defective valve. Alternatively an 866A mercury rectifier with its base adapted may be used. The effect of this added diode is to bring the average voltage level to a point where the regulators can control the remaining good grid control rectifier.

The input taps to the transformer can be adjusted to compensate for input voltage and frequency. The output dc voltage may be adjusted by the potentiometer in the grid circuit of the 6F6. This is located on the paxolin panel between the transformer taps. It is also as well to check that when the unit is put into operation the power supply is effectively grounded to the table to cut down rf hash.

The main power switch to the unit is one of two located underneath the top of the table, directly below the character counter. The left-hand one is the motor switch for the TD and the right-hand one is the main power switch. Since there is no indication that the power is "on" (other than the motors go round when they are switched on), it is wise to install a neon mains indicator on the front of the table just by the reperforating run out switch. When the power is switched on to the unit, a bi-metallic relay prevents application of ht to the thyratrons until their filaments are hot. This is in the order of 30s.

The loop selector switch is the three-position switch on the front of the table. When in the central position, the power for the loop is obtained internally and the unit is disconnected from the Demodulator loop supply. In either the left or right positions the magnets may be driven from two separate demodulators with built-in loop supplies. Since in most amateur rtty stations the keyboard and selector magnets are in series, modification of the terminal block connections is shown below. See **Fig 2.145**.

The reperforator run-out button breaks the reperforator loop only. Thus when receipt of a reperforated message is complete this button is pressed. The reperforator runs out the tape, thus ensuring that none of the message tape is left inside the machine.

The operation of the Model 15 Teletype has been described previously. The only difference between the Standard Model 15 and the printer supplied with the 19 Composite Unit is that the keyboard has the perforating attachment. This is selected by the three-position switch on the right-hand of the keyboard. The functions are as follows:

(1) "Keyboard": The tape unit is disconnected and the machine transmits and receives normally.

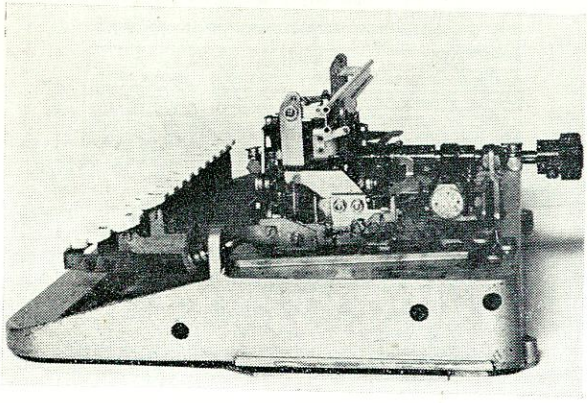
(2) "Keyboard & Tape": The machine transmits normally from the keyboard but at the same time a perforated copy of the transmitted message is made.

(3) "Tape": The machine receives normally. At the same time however, as the machine is receiving, the reply tape may be punched from the keyboard. As the keyboard punch punches all five code characters simultaneously it is possible to punch tape this way at much higher speeds than, say, in position (2) where the circuitry is arranged so that another character cannot be punched until the teleprinter has finished transmitting the previous one. A first-class touch typist can type at 75wpm. If he (or she) was typing on the keyboard and transmitting the signal the machine will only allow a maximum speed of 60wpm. However, in the "Tape" position, the typist may operate at any speed above (or below) 60wpm.

In this position, the character counter is brought into operation. When punching tape "blind" there is no means of telling whereabouts along the line across the page of the receiving machine you would be. The character counter shows the operator exact whereabouts on the line he is. A light comes on at about 70 characters (adjustable) to warn the typist that the end of the international 72-character line is near. When the CR key is pressed the counter automatically returns to zero. The counter also does not register on LTRS and FIGS signals.

The tape is transmitted at the maximum capability of the system (60wpm) by the automatic transmitter (transmitter distributor). This unit slides on to the base connections in the table. It has the same motor and governing circuitry as the motors in the Model 15 teleprinter, and a detailed description is given in Chapter 3.

* Popkin-Clurman, RTTY Journal, 15 No. 4, p15 (1967).



Teletype 15 with Lorenz LO15 keyboard. Note the oil cups at each end of the drive shaft.

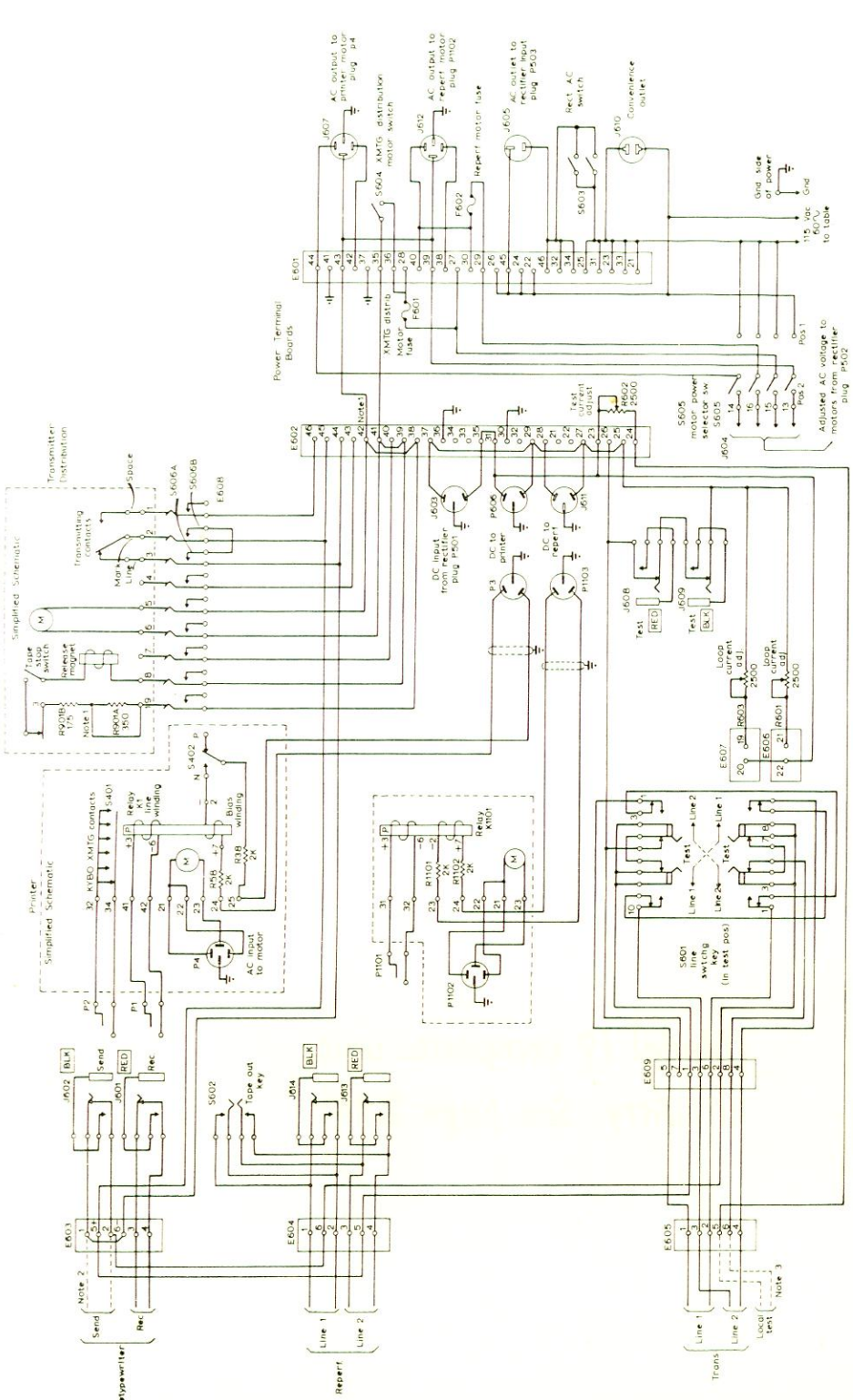


Fig 2.146. Model 19, wiring diagram.

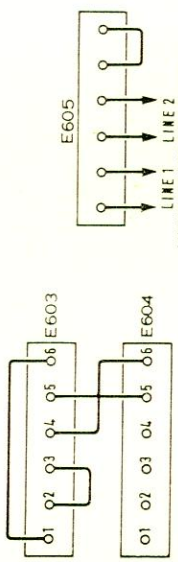


Fig 2.145. Model 19, wiring modification.

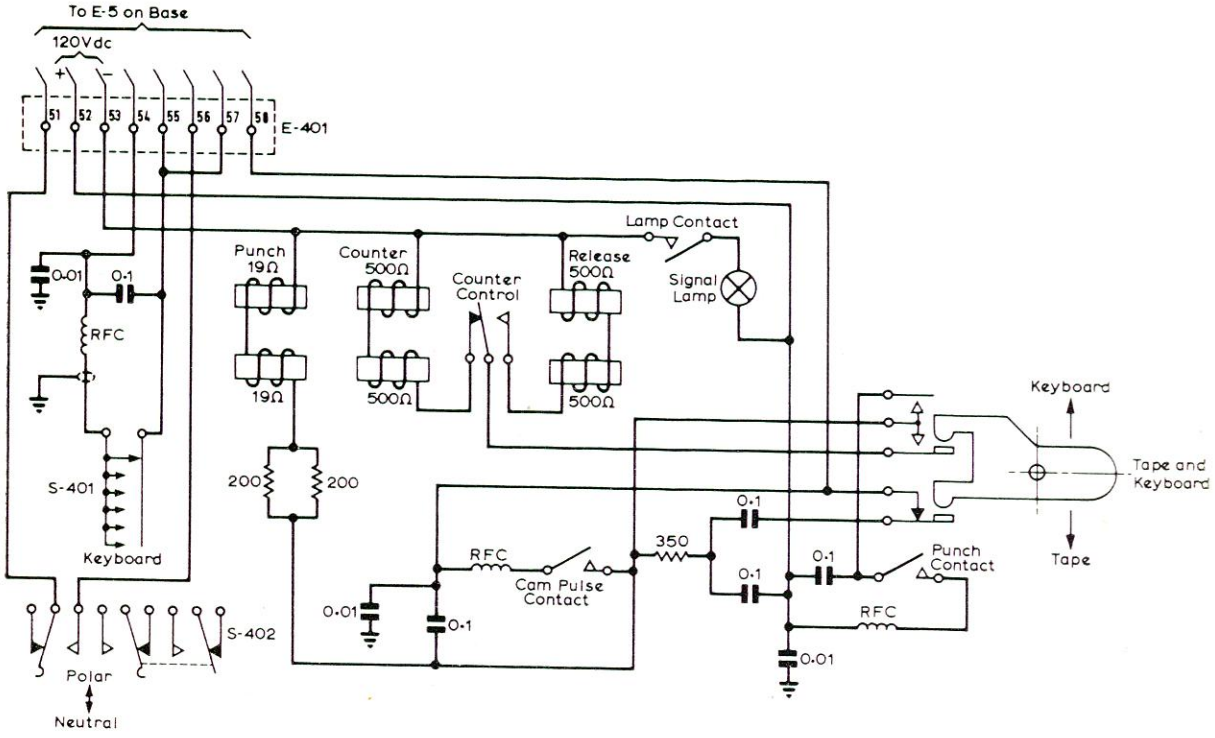


Fig 2.147. Model 19, perforator wiring diagram.

(Model 19 composite unit circuitry. See page 2.94)

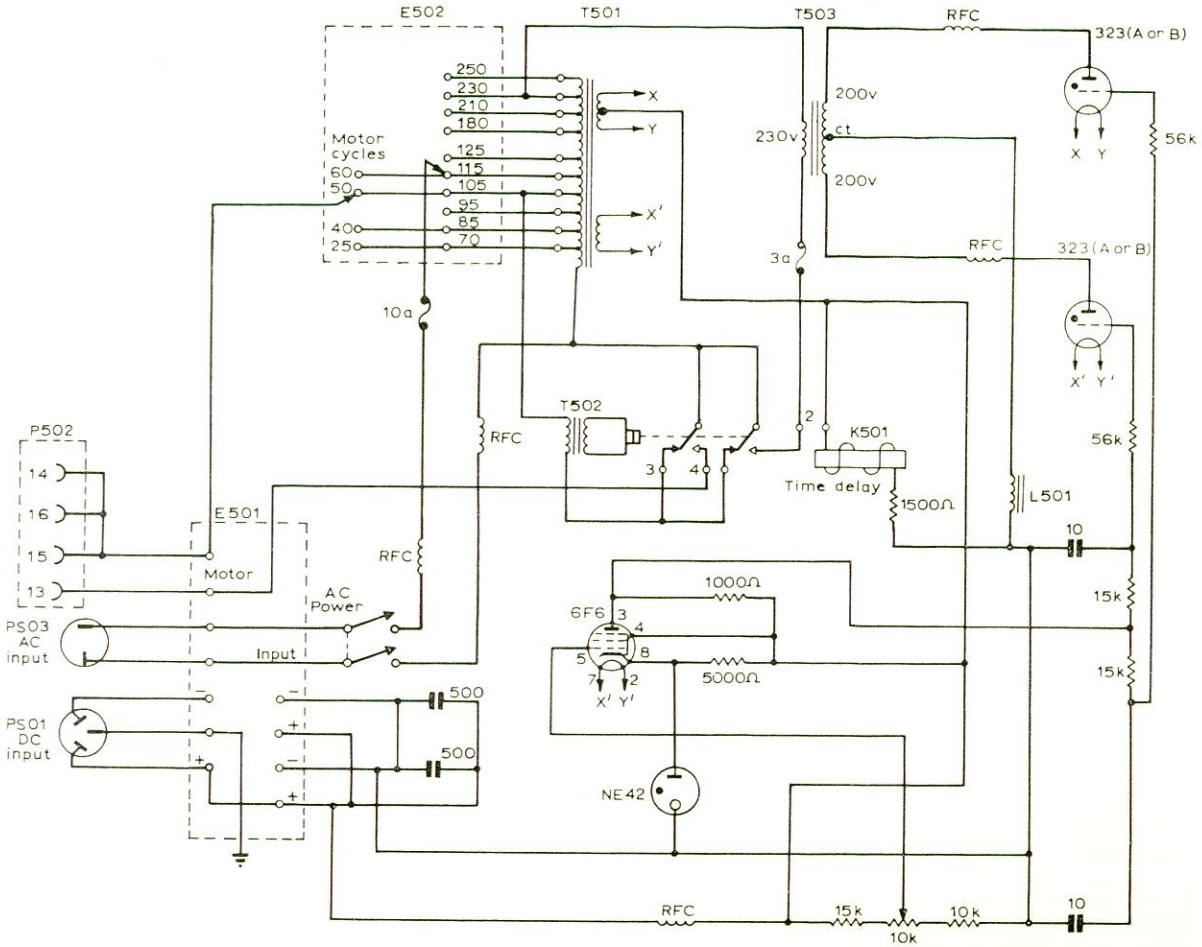


Fig 2.148. REC-30, wiring diagram.

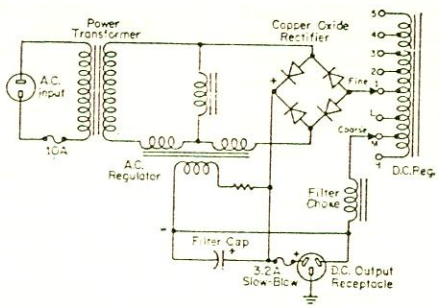


Fig 2.149. REC-6 power unit, wiring diagram.

TELETYPE 28 SERIES. SEND-RECEIVE AND RECEIVE-ONLY PAGE PRINTER SETS

General

This equipment range is fully comprehensive for communication needs where highly reliable five-unit terminals are required. The range offered is detailed below. It is provided in various forms and arrangements to suit particular requirements, including interface and local power supplies.

Automatic Send-Receive Set (ASR)
This is a complete terminal that provides for:
Tape or keyboard transmission.
Printed page and/or tape reception.
Local tape preparation.

Page Printers
(1) *Keyboard Send-Receive Set (KSR)*
Enables simultaneous printed page reception and manual transmission from a keyboard.
(2) *Receive Only (RO)*
A set for page-printing only.

Tape Punch (ROTR)
A free-standing tape reperforator.

Transmitter Distributor (LXD)
A free-standing tape transmitter.

The send-receive model provides maximum flexibility for applications requiring both transmission and reception facilities. The receive only model is identical except that it does not have the mechanisms for generating the five level start-stop signal.

The page-printer sets require two external connections: a power lead to a 110V ac or dc supply, and a signal line to interconnect associated equipment. Signal line or loop supply may be obtained from either a remote or internal dc supply. The typing unit requires a neutral signal, but provision may be made for polar input.

These machines can be fitted with a "stunt box" and so arranged to provide customer facility functions resulting from the detection of discrete combinations of characters.

Construction

Send-Receive Keyboard (LK) and Receive-only Base (LB)
Both the send-receive keyboard and receive-only provide mounting facilities for the typing unit, motor, gear bracket and the mechanisms required for local control of the page-printer set. Only the send-receive keyboard is equipped with the parts necessary for the generation and transmission of a conventional five-level start-stop signal.

The send-receive keyboard or receive-only base is attached to a shock mounted cradle assembly in the floor and table model consoles. In the rack mounted set the send-receive keyboard is attached to a base plate which is clamped to the printer cover. Design of the cover does not permit use of the receive-only base.

Signal and control leads terminate at a 21-point connector; power leads from the motor connect to a four-point terminal board. Both plug and terminal board are located at the rear of the units.

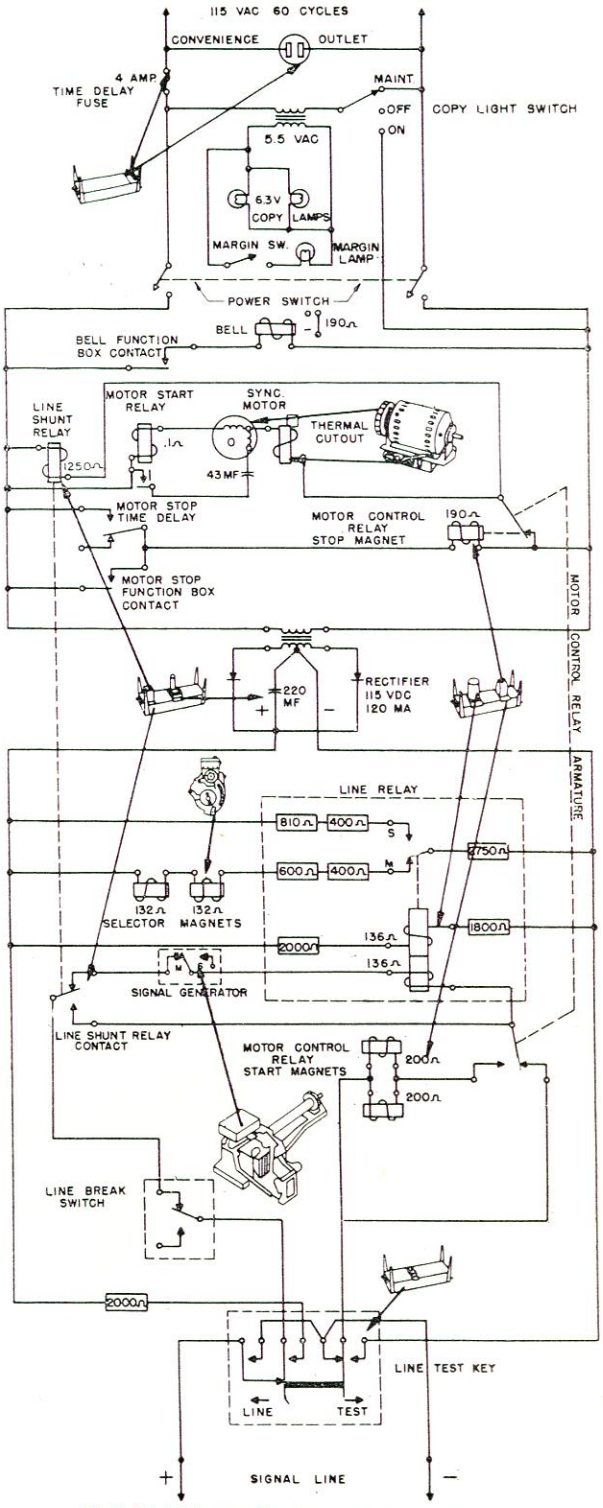


Fig 2.150. Teletype 28, simplified wiring diagram.

Typing Unit (LP)

The typing unit contains the mechanisms necessary for translating electrical input signals into printed alpha-numeric characters or functional control operations ranging from internal print suppression to supervisory control of external equipment. The unit will accommodate friction or sprocket feed paper, in single or multi-copy form, either rolled or fanfolded. Type box or individual pallet substitution is a simple operation requiring little time and readjustment.

The typing unit is mounted on either the send-receive keyboard or receive-only base and positioned on the locating studs provided. The motor power is coupled through pinion and driving gears to the typing unit's main shaft. All electrical connections terminate at a 21-point connector located on the right side frame. An additional plug is available if required.

Stunt Box

The stunt box is installed in the rear of the typing unit and driven from a clutch assembly on the main shaft. Forty-two functional control positions are provided. Less than half of these are reserved for specific functions, the remainder may be allocated for desired operations.

Individual functions mechanisms may be selected by a single character or upon the receipt of a sequence of characters. The mechanisms may be used to control the page-printer set and co-ordinate the operation of remote equipment.

Consoles (LAC and LPC)

The components of the Model 28 page-printer set may be installed in one of three consoles: The floor model, the table model or a special close-fitting cover. Power and signal lines are routed through openings in the rear of the consoles. In the rack mounted set the lines are connected to terminals in the electrical service unit. In the floor or table models the lines are connected either to rf filters if used, or directly to the terminal boards on the rear wall of the console.

Motors (LMU)

Two types are available, synchronous or ac/dc series governed, both run at 3,600rpm.

Electrical Service Unit (LESU)

The electrical service unit serves as the concentration point for the page-printer set's electrical connection. In addition to the line fuse and convenience receptable, the electrical service unit provides terminal boards and mounting facilities for optional sub-assemblies.

The unit is installed in the floor and table model consoles, behind the keyboard or base. In the rack-mounted set, the unit occupies a separate compartment.

Tape Punches

The 28ASR may be fitted with any one of four punches. These are typing and non-typing perforators and typing and non-typing reperforators. The perforators may be used for tape preparation from the keyboard, and the reperforators can produce tape punched either from the keyboard or from an incoming signal. All four versions produce chadless tape.

Transmitter Distributors (Tape Readers)

Again, one of four types of transmitter distributor may be fitted to the 28ASR.

(*a*) Fixed head single contact. Senses the code and converts this to electrical impulses in the contact box assembly and distributes them sequentially.

(*b*) Pivoted head multi-contact. Always used with a punching unit because the pivoted reader can move along the tape and read and transmit the last character punched.

(*c*) Fixed head multi-contact. Allows for the transmission of tape prepared locally on the ASR or from any outside source. Signals may be either sequential or five-wire output.

(*d*) Pivoted and fixed head multi-contact. The pivoted head portion, enclosed in the 28ASR, is in line with, and accepts tape directly from, the punch unit. The fixed head section is accessible externally for manual insertion of tape from any source. Mainly used in data processing.

DISASSEMBLY AND REASSEMBLY

General

This section is issued to describe the disassembly and reassembly procedures for the 28 typing unit. Disassembly covers a procedure for removing the principal sub-assemblies which make up the unit.

Reference should be made to the exploded views found in the appropriate parts literature for an illustration of the mechanism to be disassembled, for location and visual identification of parts, and detailed disassembly and reassembly features.

Disassembly should be confined to sub-assemblies, which can, in some cases, be removed without disturbing adjustments. When reassembling the sub-assemblies, be sure to check all associated adjustments, clearances and spring tensions.

If a part that is mounted on shims is removed, the number of shims used at each of its mounting screws should be noted so that the same shim pile-up can be replaced when the part is remounted.

Retaining rings are made of spring steel and have a tendency to release suddenly when attempting to remove them. Loss of these retainers can be minimized as follows: Hold the retainer with the left hand to prevent it from rotating. Place the blade of a suitable screwdriver in one of the slots of the retainer. Rotate the screwdriver in a direction to increase the diameter of the retainer for removal.

Avoid loss of springs in disassembly by holding one spring loop with the left hand while gently removing the opposite loop with a spring hook. Do not stretch or distort springs when removing them.

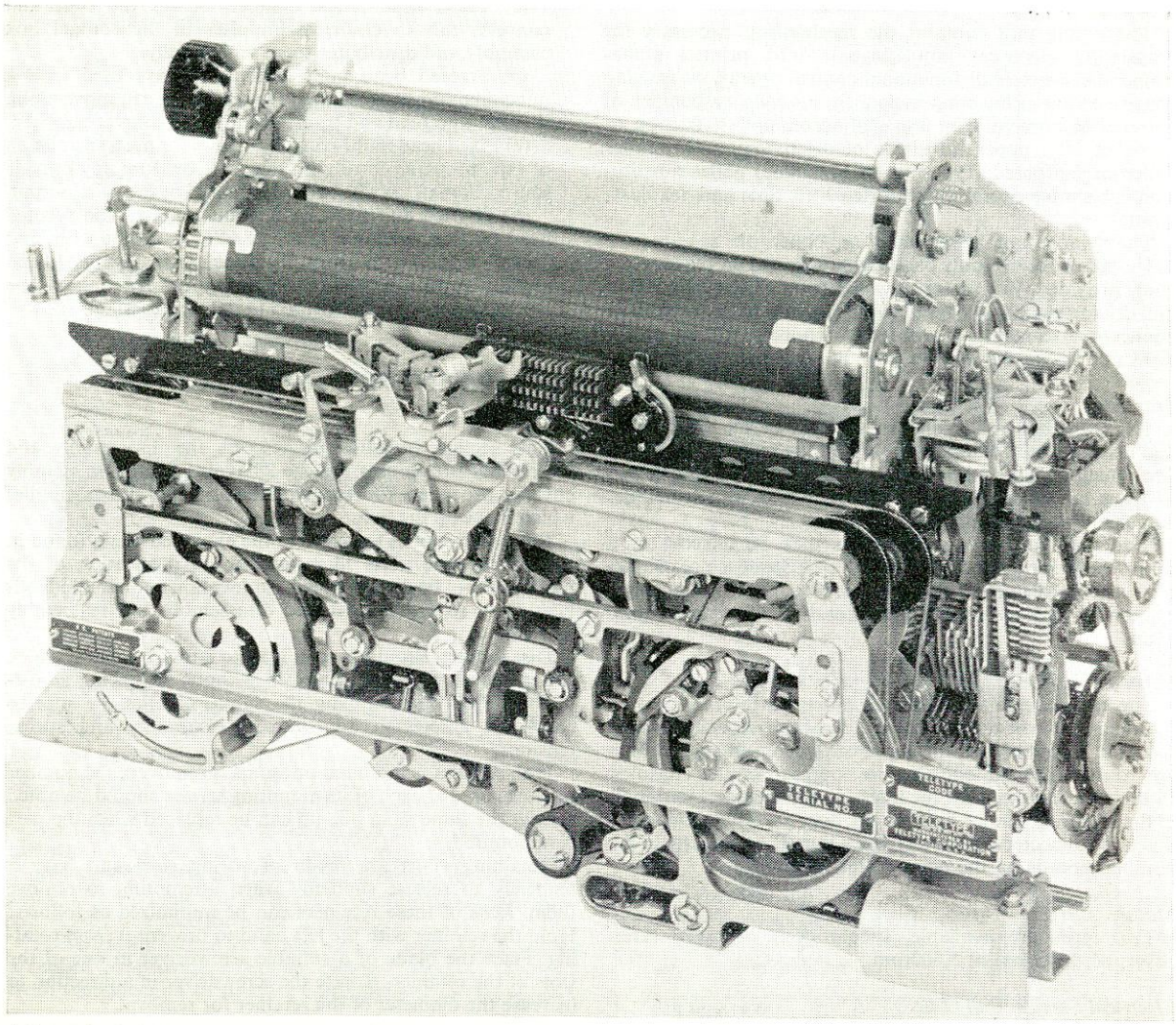
With cabinet lid raised or enclosure cover removed, loosen and remove the four screws that secure the typing unit to its base. Disconnect the cable plug connector from the side frame. Lift the typing unit off.

Disassembly and Reassembly

When removing a sub-assembly from the unit, the procedure followed and the location from which parts are removed must be carefully noted so that reassembly can be done correctly. Where no specific instructions are given for reassembly, reverse the procedure used in removing it.

Type Box

To remove: Trip the type box latch to the right. Lift the



Model 28 typing unit, front view (Illustration by courtesy of The Teletype Corporation).

right end of the type box upwards to an angle of approximately 45 degrees and pull towards the right to disengage it from the left-hand bearing stud.

To disassemble the type box for replacing type pallet or spring, proceed as follows:

(*a*) Remove both screws and nuts that secure the front plate to the rear plate assembly. Separate the two plates.

(*b*) Remove the spring from the pallet by compressing it slightly and pulling the formed end out of the slot in the pallet.

NOTE: This spring should be discarded once it has been removed from its assembly.

(*c*) When installing the new spring, make certain that the formed end extends through the slot in the pallet.

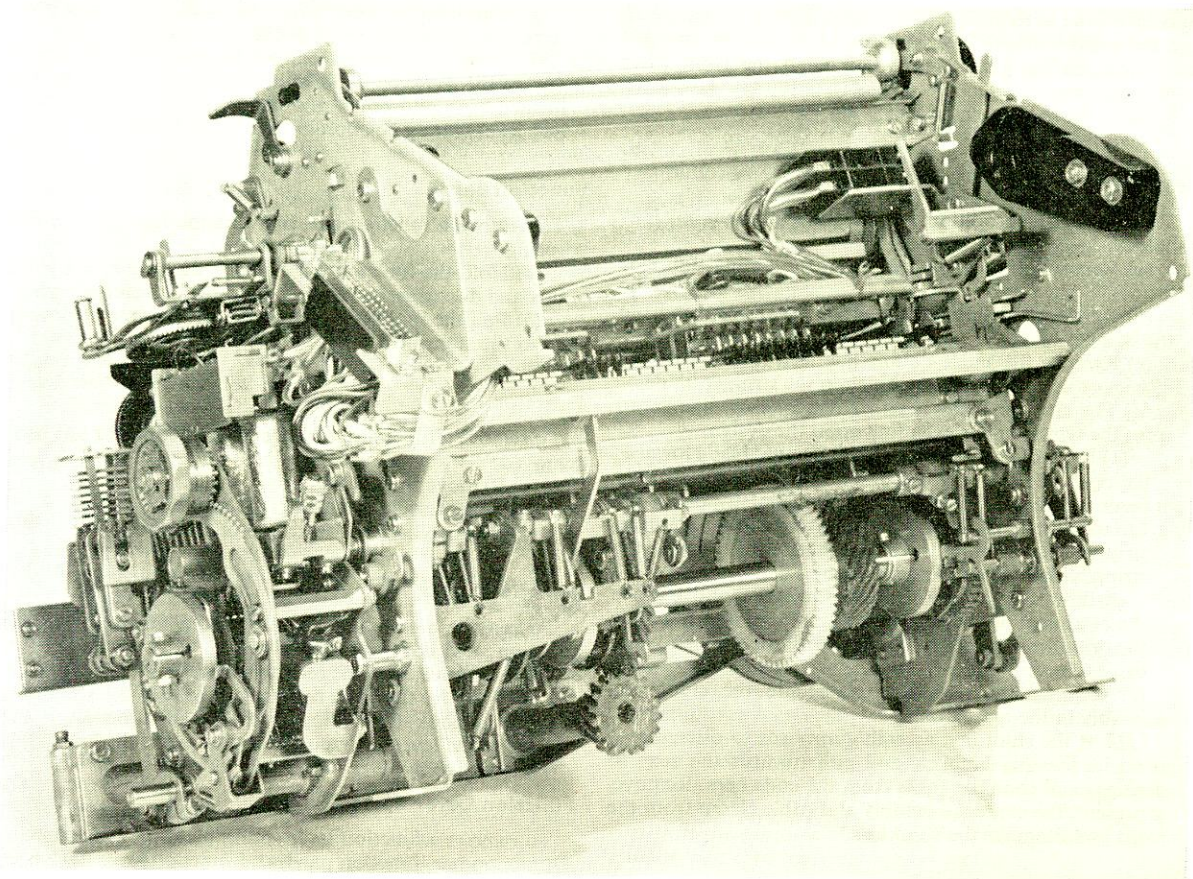
(*d*) To reassemble the type box, line up the front plate with the rear plate assembly and draw the two plates together until the head of the pallet leaves the rear plate by approximately $\frac{1}{16}$in. This may be accomplished by using two 6-40 screws (at least $\frac{11}{32}$in long) and nuts in place of the two screws and nuts removed when disassembling, and tighten them only enough to hold the pallets as specified above. Do not clamp the plates together until all pallets have been moved into their correct position.

(*e*) Manipulate the pallets until they fall into their respective openings in the front plate. Press the plates together.

(*f*) Replace the screws and nuts used in step (*d*) with screws and nuts removed in step (*a*)

To replace type box: reverse the procedure used in removing it.

CAUTION: To avoid springing the type box latch, the type box should be firmly seated on the bearing stud and the point of the latch should be placed in the notch of the type box plate before moving the latch to its locked position.



Model 28 typing unit, rear view (Illustration by courtesy of The Teletype Corporation).

Printing Carriage

To remove: Loosen the two screws in the printing carriage clamp plate and disengage the carriage from the upper draw-wire rope. Move the carriage to the left of its track and tilt the lower part forward to disengage the rollers from the track.

To replace: Make certain that the printing arm is correctly re-engaged with the printing track. Position the carriage clamp on the upper draw-wire rope for the correct printing carriage position.

Type Box Carriage

To remove: Move the type box carriage to its extreme right hand position.

(*a*) Select any character in the bottom row of the type box and rotate the main shaft until the type box carriage is in the uppermost position.

(*b*) Remove the ribbon from the ribbon guide.

(*c*) Remove the retainer ring from the stud in the right hand end of the type box carriage link. Disengage the link from the carriage.

(*d*) Hold the ribbon guide forward and the right ribbon reverse lever back. Pull the carriage towards the right to disengage it from the carriage track.

Front Plate

To remove: Manually move the type box carriage to the extreme right. Select any character in the bottom row of the type box and rotate the main shaft until the type box carriage is in its uppermost position.

(*a*) Remove the retainer ring from the type box carriage link right hand stud and disengage the link from the carriage.

(*b*) Remove the three screws which secure the main ball drive bracket to the rocker shaft.

(*c*) Remove the spacing shaft gear.

(*d*) Remove the four screws which secure the front plate assembly to the typing unit side frames.

(*e*) Pull the front plate assembly forward to disengage it from its connecting parts in the typing unit.

To replace front plate: Make certain that the code bar bellcranks, the letters-figures shift slide, the reversing slide

shift lever, the automatic CR-LF bellcrank, if so equipped, and the carriage return lever extension are properly engaged with their mating parts before tightening the front plate mounting screws.

Replace the spacing shaft gear.

Stunt Box

To remove: The procedure for removing the stunt box is as follows:

(*a*) Remove the rear tie bar from the typing unit side frames.

(*b*) Remove the line feed function pawl stripper from the stripper blade.

(*c*) Remove the single-double line feed lever screw and disengage the lever from the notch in the stripper blade.

(*d*) The stripper blade is either removed or disengaged from the typing unit, depending upon the design.

(1) For earlier design: Hold the stripper blade towards the right side of the typing unit and unhook the stripper blade left arm from the blade. Pull the stripper blade towards the left side of the typing unit to disengage the stripper blade from the right hand arm. Remove the stripper blade from the typing unit.

(2) For later design: Loosen the screw and remove the retaining ring from the camshaft drive arm. Slide the drive arm out of engagement with the stripper blade drive arm.

(*e*) Remove the screws which secure the stunt box assembly in the typing unit.

(*f*) Lift the stunt box assembly upwards to disengage it from its locating brackets and pull towards the rear to disengage all code bar forks from the code bars. Remove, if present, the contact assembly and cable clamp from the stunt box. Remove the stunt box.

Stunt Box Switch

To replace the contact arm in a stunt box switch, remove the two screws that hold the contact plate to the block.

(*a*) Carefully unsolder the wire from the contact arm spring. (It is not necessary to unsolder the contact arm spring wire from switches having the contact spring.)

(*b*) Remove the contact plate assembly from the contact block.

(*c*) Remove the contact arm(s) from the contact plate assembly.

(1) For earlier design: slip the contact arm spring from the contact plate.

(2) For later design: slip the contact arm spring out of engagement with the centre lug of the section being replaced.

(*d*) Place the new spring in position on the contact plate.

(*e*) Before mounting the contact plate on the block, make sure the end of the spring rests on top of the formed-over portion of the contact clip. There should be some clearance between the low end of the spring (front) and the upper edge of the contact arm to avoid interference with the normal movement of the contact arm.

(*f*) Replace the contact plate assembly, with the contact arms removed, into the contact block. Mount the contact block in the required location with the two screws friction tight.

(*g*) Carefully resolder any leads that may have been removed, being careful to avoid overheating.

(*h*) Insert the pointed end of the contact arm, notch downward, between the bent up end of the spring and the formed-over portion of the contact clip. Push the arm into its operating position in the contact block.

Function Bar

To remove a function bar, first unhook the function bar spring.

(*a*) Hold the function bar towards the rear of the stunt box and disengage its function pawl from the function bar.

(*b*) Pull the function bar towards the front to remove it from the stunt box.

Function Pawl

To remove a function pawl after the function bar has been removed:

(*a*) Remove the pawl spring.

(*b*) Hold associated function lever back.

(*c*) Remove the pawl from top of stunt box.

Function Lever

To remove a function lever after the function bar and function pawl have been removed:

(*a*) Remove the shaft retainer plate.

(*b*) Remove the shaft nearest the front of the stunt box.

(*c*) Unhook the spring from the function lever and remove the lever through the top of the stunt box.

Function Lever Spring Plate

To remove a function lever spring plate or latch after the function bar, function pawl, and function lever have been removed:

(*a*) Loosen the screws that fasten the three guide blocks to the lower side of the guide bar.

(*b*) Remove the spring from the spring plate or latch.

(*c*) Pull downwards on the function lever spring plate or latch to snap it out of engagement with the retainer shaft.

To replace the stunt box, push it forward in its guide rails to within $\frac{1}{8}$in of its final position.

Manually disengage the function pawls from their function bars and push the stunt box assembly forwards and downwards until it is latched in place on its locating brackets.

Replace the stunt box mounting screws, receptable, and selector magnet wires.

Code Bars

To unblock the suppression code bar, loosen the screw that mounts the code bar clip and the retaining plate to the left hand code bar guide bracket, and rotate the code bar clip up out of engagement with the suppression code bar. Tighten the screw.

To remove the code bar assembly: first, remove the stunt box assembly and the front plate assembly as previously described.

(*a*) Remove the screws and lock washers which secure the code bar assembly to the side frame.

(*b*) Remove the code bar shift bar retainer plate from the right hand code bar guide bracket.

(*c*) Unblock the suppression code bar. Remove the code bar shift bars and springs from the code bars and pull the code bar assembly forward and to the left.

To reinstall code bar assembly: reverse the procedure used in removing it, except do not tighten the mounting screws.

(*a*) Hook the short extension of the spring in the spring hole of the code bar. The short extension of the spring should be hooked from the bottom of the code bar, and the long extension should be hooked over the top of the code bar shift bar.

(*b*) Loosen the code bar assembly tie bar screws and hold the code bar guide brackets back and downward firmly against their locating surfaces on the side frame and tighten the four mounting screws.

(*c*) Tighten the two tie bar screws.

Main Shaft

To remove main shaft: the selector cam-clutch assembly must be removed.

(*a*) Set the typing unit upside down.

(*b*) Return the carriage to its left hand position.

(*c*) Remove the screw that secures the spacing shaft in the spacing collar.

(*d*) Remove the spacing shaft with gear.

(*e*) Remove the screw that secured the collar and the clamp to the right end of the main shaft.

(*f*) Remove the main shaft right hand bearing retainer plate.

(*g*) Remove the retainer plate at the clutch bearing and remove the link.

(*h*) Remove the two screws from the main shaft left hand bearing clamp.

(*i*) Unhook the springs from the trip levers and latch levers associated with the clutches. Position the code bar clutch so that the low part of the clutch cam clears the spring arm on the cam follower. Unhook the code bar clutch cam follower spring.

(*j*) Remove the function clutch arm by removing two screws and retainer ring if present.

(*k*) Unhook the spring from the function bar reset bail.

(*l*) Move the main shaft assembly towards the left to disengage the code bar clutch and function clutch links from their connecting pins.

(*m*) Lift the left end of the shaft assembly out of the side frame. Position the shaft so that the function clutch link passes the suppression assembly bracket, then remove the shaft assembly from the typing unit.

NOTE: Disassembly of the main shaft and clutch assemblies can be accomplished by referring to the exploded views contained in the manufacturers' parts literature. It should be noted that when assembling clutches having cams and discs marked "O" for identification, the marked side of the parts should face away from the clutch side of the assembly. Function and code bar clutches should have their driving links assembled so that the longer end of the hub faces away from the clutch side of the assembly.

To reinstall shaft assembly: reverse the procedure used in removing it. The line feed clutch spur gear should be positioned with its flat side towards the line feed clutch spacer and with the indentation in the gear towards the special washer between the gear and the main shaft ball bearing.

Upper Draw Wire Rope

To remove upper draw wire rope: return the carriage to the left hand position.

(*a*) Loosen the nut on the front end of the spring drum stud. Operate the ratchet escapement lever to unwind the carriage return spring.

(*b*) Remove the upper draw wire rope from the clamp plate on the printing carriage, and the clamp on the oscillator rail slide.

(*c*) Loosen the clamping screw that secures the upper draw wire rope to the spring drum. Remove the wire rope from the drum.

(*d*) Remove the screw in the spacing drum that secures the ends of the wire rope. Remove the rope from the drum.

Lower Draw Wire Rope

To remove lower draw wire rope: remove the screw that secures the wire rope to the spacing drum. Remove the end of the rope from the drum.

(*a*) After loosening the screws that secure the margin indicator cam disc on the spring drum, position the disc to expose the lower draw wire rope mounting screw.

(*b*) Remove the lower draw wire rope screw and rope from the spring drum.

(*c*) Loosen the screws in the pulley bearing studs that mount draw wire rope pulleys and move the studs towards the centre of the typing unit.

To replace draw wire rope: make certain that the lower draw wire rope is in front of the upper draw wire rope in the track around the drums.

Adjust the position of the type box, the printing carriage, and the wire rope tension.

Platen (Friction Feed)

To remove platen: remove the line feed spur gear.

(*a*) Remove the platen bearing retainers.

(*b*) Remove the paper straightener shaft.

(*c*) Hold off the detent and lift the platen out of the side frame.

When replacing each platen bearing retainer, put its upper screw in first. Leave the screw slightly loose. Press the lower end of the retainer downward and hook it into the elongated hole in the side frame. Replace the lower screw. Tighten both screws.

To remove platen: Remove the paper fingers or guide bracket assembly.

(*a*) Remove the spur gear from the left end.

(*b*) Remove the platen bearing retainers.

(*c*) Hold off the detent bail and remove the platen.

(*d*) Remove the sprocket hub assembly from the platen assembly.

(*e*) Insert the shaft tool into the hub and fasten it with the screw.

(*f*) Remove the clamp and cam from the assembly.

(*g*) Insert the hub into the retaining tool.

NOTE: These tools must be used when disassembling the platen hub in order to hold the spring loaded pins in place when the feed cam is replaced.

To replace a pin: rotate the hub assembly within the retaining tool, with a tommy wrench inserted in the shaft tool, until the desired pin is opposite the notch in the retaining tool. A pin may then be removed or replaced. Grease pin cylinder liberally before inserting new pin.

CAUTION: While rotating the hub, the notch must be covered to prevent the pins from being released. Since the pins are spring loaded, they can eject with considerable force.

To replace platen: reverse the procedure used in removing it. When replacing the right sleeve bearing, the chamfer side or side marked "O" must face the end of the shaft and the wide part placed toward the front of the unit. When replacing each platen bearing retainer, put its upper screw in first. Leave the screw slightly loose. Press the lower end of the retainer downwards, and hook it into the elongated hole in the side frame. Replace the lower screw. Tighten both screws.

Selector Cam-Clutch

To remove selector-cam clutch: facing the right end of the typing unit, lift the push lever reset bail from its cam, and move the push lever reset bail to the rear, latching it in the raised position on the push lever guide. Push the marking lock lever (and the blocked selector levers) to the left until the selector magnet armature latches the marking lock lever.

(*a*) Remove the screw which secures the selector clutch drum to the main shaft. Position the clutch cam disc so that the stop lug is in the uppermost position.

(*b*) Hold the start lever and spacing lock lever away from the selector cam-clutch assembly; grasp the selector cam-clutch by the clutch cam disc (not by the drum) and pull forward by rotating the cam-clutch slowly.

CAUTION: The cam-clutch should come off the main shaft easily. Do not force it.

To replace cam-clutch assembly. Reverse the procedure used in removing it except as the cam-clutch approaches its fully installed position, move the trip shaft lever and clutch latch lever so that they ride on their respective cams. Restore the push lever reset bail and the armature to their operating positions.

Selector Mechanism

To remove selector mechanism: the cam-clutch assembly must first be removed from the main shaft.

(*a*) Remove the screw that secures the selector mechanism to the intermediate bracket on the code bar positioning mechanism.

(*b*) Remove from the selector mechanism the spring which connects with the common transfer lever on the code bar positioning mechanism.

(*c*) Remove the remaining three selector mounting screws and lift the selector from the main shaft bearing housing.

Code Bar Positioning Mechanism

To remove code bar positioning mechanism: unhook from the selector the spring attached to the common transfer lever and restore any operating push levers to the spacing position by raising the push lever reset bail.

(*a*) Loosen the clamp screw on the shift lever drive arm, and remove the two screws which mount the mechanism—one to the side frame and one to the selector mounting plate.

(*b*) Manipulate the transfer levers and code bar shift bars while gently twisting the mechanism off the code bar shift bars.

To replace code bar positioning mechanism on the typing unit: rotate the main shaft to the stop position; push the code bar shift bars to the marking position. Manipulate the code bar shift bars and transfer levers so that the shift bars line up with their respective slots in the bracket, and slide the shift bars through the slots, one at a time, leaving the bottom slot vacant.

Rangefinder Assembly

To remove rangefinder assembly: remove the two screws and the nut that secure the rangefinder plate to the selector mounting plate. Move the stop arm bail forward so that it disengages from the start lever and clears the selector clutch disc, while rocking the rangefinder assembly back and forth as it is removed.

To replace rangefinder assembly: reverse the disassembly procedure.

NOTE: For units equipped with the bail lever guide, do not tighten the nut until the bail lever guide adjustment has been checked.

Selector Magnet Assembly

To remove selector magnet assembly: remove the two screws and nut which mount the range finder to the selector.

(*a*) Remove the selector magnet cable from the coil terminal screws.

(*b*) Remove the two magnet mounting screws and lift the assembly out.

TELETYPEWRITER BASE (KSR and RO)

General

This section provides instructions for disassembly and reassembly procedure for the 28 keyboard and base units.

Disassembly as outlined in this section covers a procedure for removing the main sub-assemblies. For additional information, refer to the manufacturers' parts literature for exploded illustrations of mechanisms to be disassembled and for visual identification.

If possible, disassembly should be confined to sub-assemblies, many of which can be removed without disturbing adjustments. When reassembling the sub-assemblies, be sure to check all associated adjustments and spring tensions.

Many parts are secured by retaining rings which have a tendency to release suddenly when being removed. Loss of these retainers can be minimized by placing a forefinger over the retainer; then place the blade of a suitable screwdriver in one of the slots of the retainer and rotate the screwdriver in a direction to increase the diameter of the retainer for removal.

The loss of tension springs may also be avoided by placing a forefinger over one end while unhooking the other end with a spring hook. Avoid stretching or mutilating the springs when removing or replacing them.

CAUTION: Remove power from unit.

Disassembly and Reassembly

NOTE: In the absence of reassembly notes, reassemble the mechanisms by reversing the procedure used in removing them.

A. Later design keyboard—KSR (this keyboard may be identified by noting that the transfer lever locking bail locks the transfer levers underneath the top portion of the transfer lever) and receive-only base (RO).

Removal of Signal Generator Assembly:

(1) Remove the typing unit, if present.

(2) Remove the contact box cover and disconnect the signal line leads from the contact terminals.

(3) Remove the two mounting screws at the front of the signal generator frame and the mounting screws at the right rear of the frame.

(4) Lift the signal generator carefully, while holding the universal bail back so that the nonrepeat lever clears and its spring will not be stretched excessively.

CAUTION: If the nonrepeat lever is pulled down as much as 90 degrees from its normal position, the nonrepeat lever spring may be stretched beyond its elastic limits. This may cause a malfunction in operation of the unit.

Removal of Label Set Windows and Label Sets, Keyboard Hood, Keyboard Front Seal and Keyboard Seal Plates:

(1) Remove the four special screws that secure the label set windows and label sets.

(2) Remove the two screws under the keyboard hood that hold the keyboard hood to the hood mounting bracket; and remove the four screws on top of the keyboard hood which hold it to the left and right frame mounting brackets.

(3) Pull the keyboard hood forward and remove it.

(4) Stretch the keyboard front seal (rubber) off the keyboard upper and lower seal.

(5) Remove the four screws that retain the two hood mounting brackets and remove the brackets.

(6) Remove the keyboard upper seal plate by unscrewing the three screws at its rear.

(7) Remove the keyboard lower seal plate by unscrewing the two screws at its front.

Removal of Keyboard Assembly:

NOTE: It is easier to disassemble and reassemble the keyboard assembly when it is resting on its rear.

(1) Remove the typing unit in accordance with the section covering disassembly and reassembly of the 28 typing unit.

(2) Remove the signal generator assembly.

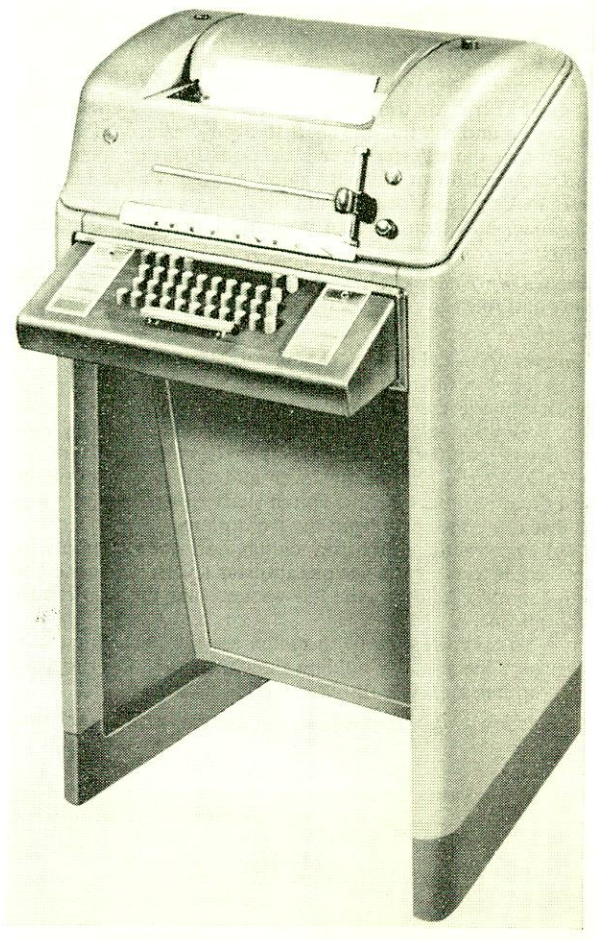
(3) Remove the label-set windows and label sets, the keyboard hood, keyboard front seal, and the keyboard seal plates.

(4) Remove the four screws that hold the left and right frame mounting brackets to the front of the keyboard base.

(5) Remove the screws that hold the right and left code-lever guide brackets on the top of the keyboard base, and the two screws, at the extreme right and left of the front bracket, which hold the front bracket to the keyboard base.

(6) Remove the four screws in the front of the keyboard base and the four screws on top of the keyboard base.

(7) Tip the front of the keyboard assembly upward and pull it forward, disengaging the function levers.



The Model 28KSR.
(Illustration by courtesy of the Teletype Corporation)

Reassembly Notes

Note 1: Make sure that all of the function levers except the keyboard lock function lever are under their corresponding functions bails.

Note 2: Depress the keyboard lock key lever so that the keyboard lock function lever will go into its position over its bail, instead of under as the other function levers should.

Removal of Signal Generator Contact Box Assembly:

(1) Remove the signal generator contact box cover and disconnect the signal line leads.

(2) Unhook the toggle drive link spring.

(3) Unscrew the two screws, at the front of the signal generator front plate, that hold the signal generator contact box assembly.

(4) Disengage the drive link from the transfer bail and lift off the signal generator contact box assembly.

NOTE: If it is necessary to provide new contacts, install an entire contact assembly instead of individual contacts.

Removal of Transfer Lever Locking Bail:

(1) Remove the signal generator assembly.

(2) Remove the signal generator contact box assembly.

(3) Remove the transfer lever locking bail spring.

(4) Take out the transfer lever locking bail by unlatching the clutch and rotating the shaft to position the cam in such a way that the transfer lever locking bail can be unhooked and dropped down from its guide post. Turn the transfer lever locking bail clockwise until it forms a right angle with its guide, and then remove it through the bottom of the frame.

Reassembly Note: It may be necessary to move the shaft back and forth to position the cam for maximum clearance.

Removal of Signal Generator Shaft and Cam Assembly:

(1) Remove the transfer lever locking bail.

(2) Remove the two screws that mount the clutch shaft rear mounting plate to the signal generator frame, and remove the nut that locks the shaft to the front of the frame.

(3) Hold the clutch latchlever and the clutch stoplever away and pull back on the clutch shaft rear mounting plate to disengage the shaft from the front plate.

(4) Remove the entire cam, clutch, and shaft assembly by rotating it to clear the various transfer levers. The code bar bail eccentric follower, the felt washer, and the cam spacer will fall free.

(5) To take the cam (with clutch assembly) off the shaft, disengage the shaft by holding the clutch shoe lever against the stop lug, and slide the cam and clutch off.

Reassembly Note: Reposition the code bar bail eccentric follower, felt washer and cam spacer before reassembling the signal generator cam and shaft assembly.

Removal of Keytop Guide Plate:

(1) Remove the label set windows, label sets, and keyboard hood.

(2) Remove the spacebar by unscrewing the two shoulder screws that fasten it to the space bar bail.

(3) Remove the screw from under the space bar on the key top guide plate and remove the two screws, in the upper corners of the key top guide plate, which hold the key top guide plate to the frame.

(4) Remove the keytop guide plate by working it off the key tops. (Let the key levers fall freely.)

Reassembly Note: Position all of the key levers to the rear. Place the front end of key top guide plate down on the frame; and push the key levers into their respective holes, starting with the bottom row and proceeding upwards towards the top row.

B. Earlier design keyboard—KSR (this keyboard may be identified by noting that the transfer lever locking bail locks the transfer levers at the top of the transfer levers) and receive-only base (RO).

Removal of Keyboard or Base Assembly:

(1) Remove the typing unit, if present, in accordance with the section covering disassembly and reassembly of the 28 typing unit.

(2) Remove the four screws (one at each corner of the keyboard or base) that secure the keyboard or base to the cradle assembly.

(3) Remove the keyboard plug connector from its keyboard receptable connector on the left rear corner of the keyboard or base.

(4) Lift the keyboard or base from the cradle assembly.

Removal of Signal Generator Assembly (Keyboard):

(1) Remove the typing unit in accordance with the section covering disassembly and reassembly of the 28 typing unit.

(2) Remove the signal generator guard bracket, if present.

(3) Remove the two screws located to the right and left of the contact box and raise the contact box. (Do not unsolder the connections if the contact box is connected to metal tubing.) If the wire connections to the contact box are flexible, unsolder the wires inside the box and do not remove the contact box.

(4) Remove the four screws that mount the signal generator casting (two at the front of the casting and two at the rear). If the keyboard is equipped with an electrical signal line break mechanism, remove the mechanism by removing its two mounting screws.

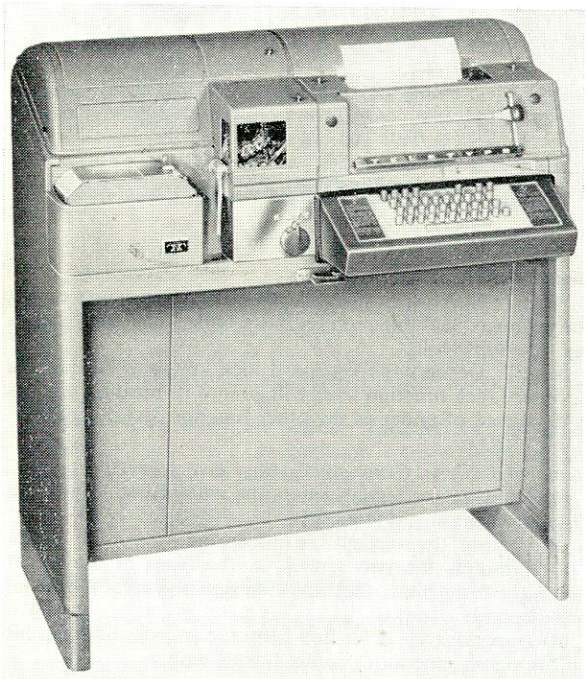
(5) Lift the signal generator upward from the keyboard.

Reassembly Notes

Note 1: Position the code bar bail latch under the code lever bail latch lever, in the notches of all the code bars, and in the notches of the trip bar and upstop bar.

Note 2: Put the breakrod in its guide hole.

Note 3: Place the clutch trip bail extension in the clutch trip bar notch.



The Model 28ASR (Illustration by courtesy of The Teletype Corporation).

Removal of Signal Generator Shaft and Cam Assembly (Keyboard):

(1) Remove the signal generator.
(2) Disconnect the clutch latch lever spring.
(3) Disconnect the clutch stop lever spring.
(4) Disconnect the flutter lever spring.
(5) Remove the front nut of the signal generator shaft.
(6) Remove the two screws that hold the signal generator rear plate to the casting.
(7) Remove the signal generator shaft assembly by lifting it upward and pulling it to the rear simultaneously.
(8) Remove the signal generator cam assembly.

Reassembly Note: Check that the clutch is fully seated and engages the drum.

Removal of Label Cover and Keyboard Label Set (Keyboard or Base):

(1) Remove the label mounting screw (or screws).
(2) Picking up the label cover at the top edge first, remove the cover and the keyboard label set.

Removal of Key Lever Assembly Cover (Keyboard or Base):
(a) Keyboard

(1) Remove the label cover and the keyboard label set.
(2) Remove the four screws located under the keyboard label set (two at the extreme right side and two at the extreme left).

NOTE: Support the key lever assembly cover while removing the screws.

(3) Pull the key lever assembly cover forward to remove it.

(b) Base

(1) Remove the two screws located inside the sealing plate (one at the right side and one at the left).
(2) Remove the key lever assembly cover by pulling it forward and downward to disengage it from the two studs near the bottom.

Removal of Key Lever (Keyboard):

(1) Insert the small lug of the key lever remover tool in the slot of the key lever and engage the shoulder of the larger lug on the top of the code lever. Pry upward to snap the key lever from the stud on its code lever.
(2) Remove the key lever. (The plastic key top should not be removed from any key lever to change a character.)

Reassembly Notes

Note 1: Support the code lever so that it will not be forced down when the key lever is later re-engaged with the stud on its code lever.

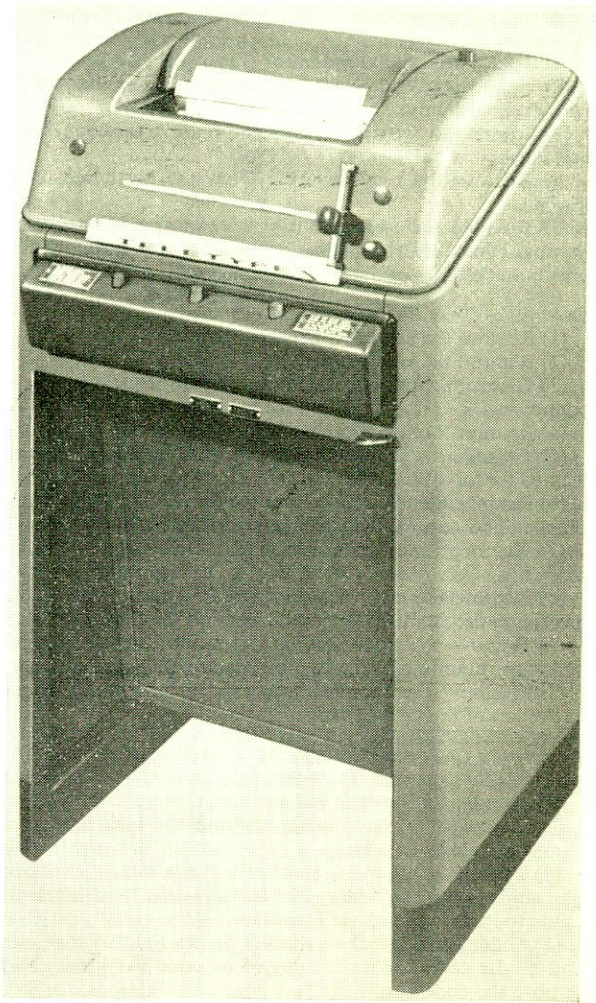
Note 2: Make sure that the key lever is restored to its proper position in the key top guide plate.

Removal of Space Bar (Keyboard):

(1) Remove the key lever assembly cover.
(2) Remove the two shoulder screws on the left and right sides of the space bar.
(3) Remove the space bar.

Removal of Key Top Guide Plate (Keyboard):

(1) Remove the key lever assembly cover.
(2) Remove the space bar.
(3) Remove the six mounting screws located on the top of the key top guide plate.



The Model 28RO (Illustration by courtesy of The Teletype Corporation).

(4) Remove the key top guide plate.

Removal of Lockball Channel (Keyboard):

(1) Remove the key lever assembly cover.
(2) Remove the two lockball channel mounting screws at the right and left ends.
(3) Pull the lockball channel forward, being careful not to drop any of the wedges that are located on the code levers.

Reassembly Note: Reinstall the wedges individually.

Removal of Sealing Plate (Keyboard or Base):

(1) Remove the key lever assembly cover.
(2) Remove the key levers (keyboard only).
(3) Disconnect the space code lever extension (keyboard only) at its snap connection.
(4) Remove all the sealing plate mounting screws.
(5) Remove the sealing plate.

Removal of Keyboard Lock and Local Line Feed Mechanism (Keyboard and Base):

(1) Remove the signal generator (keyboard only).

(2) Unhook the code lever bail spring from the code lever bail (keyboard only).

(3) Loosen the two pilot screws and remove the code lever bail (keyboard only).

(4) Remove the retaining ring from the local line feed tripbail.

(5) Remove the two mounting screws and remove the keyboard lock and local line-feed mechanism through the hole in the bottom of the keyboard or base.

Removal of Code Bar Assembly (Keyboard)

(1) Remove the key lever assembly cover.

(2) Remove the key levers.

(3) Disconnect the space code lever extension at its snap connection.

(4) Remove the signal generator.

(5) Remove the four code bar assembly mounting screws located on top of the code bar frame.

(6) Remove the two screws that mount the carriage-return bracket, and remove the carriage-return bracket.

(7) Remove the keyboard-lock and local linefeed mechanism.

(8) Remove the nut that secures the code-lever-bail latch lever, and then remove the latch lever and its spring.

(9) Remove the three screws that mount the non-repeat bellcrank mounting plate assembly, and remove the assembly.

(10) Remove the code bar assembly through the opening in the top of the keyboard.

Removal of Code Bar (Keyboard):

(1) Remove the code bar assembly.

(2) Disconnect the code bar springs.

(3) Remove the mounting screw and the lock bar pawl from the code lever guide.

(4) Loosen the mounting screws for the left and right code bar guides until the screws are friction-tight, and lift each guide to its extreme upward position.

(5) Slide the code bar to the left or the right so that one end of the code bar moves out of its code bar guide, and remove the code bar.

ELECTRICAL SERVICE UNITS

General

This section provides disassembly and reassembly instructions for 28 electrical service units used in teletypewriter sets.

When it is necessary to remove the various components from the electrical service unit, the appropriate wiring diagrams should be used as a reference.

After the disassembly procedure has been followed, reassembly procedure for most components is obviously a reversal of the disassembly procedure. Where necessary, reassembly information is given.

NOTE: Remove power from unit before starting disassembly procedure.

Disassembly and Reassembly

Removal of 28 Electrical Service Unit from 28 Teletypewriter Cabinet used with 28 Keyboard Send-Receive (28 KSR) or Receive-Only (28 RO) Teletypewriter.

(1) Raise dome of cabinet and disconnect all plugs and receptacles from the typing unit.

(2) Remove the typing unit in accordance with the section entitled "28 Typing Unit, Disassembly and Reassembly".

(3) Disconnect all plugs and receptacles from the keyboard and remove the keyboard.

(4) Remove the mounting studs from each end of the electrical service unit.

NOTE: The electrical service unit may now be turned upside down for servicing or un-wiring components.

(5) The various components may be removed from the unit by removing their mounting screws on the top side of the unit and disconnecting cabling and wires.

(6) If it is desirable to remove the electrical service unit completely from the cabinet, disconnect the remaining wires and cables.

Removal of Electrical Service Unit from Skin-Tight KSR Sets (located behind the typing unit cover):

(1) Unlatch electrical service unit cover at each end and lift cover off.

(2) Remove the mounting studs from each end of the electrical service unit and lift unit off base.

(3) Remove various components from the electrical service unit by removing their mounting screws and disconnecting wire or cable connections as necessary.

Removal of 28 Electrical Service Unit from 28 Automatic Send-Receive Sets (28 ASR):

(a) Without auxiliary equipment

(1) Raise the dome of the cabinet and disconnect all plugs and receptacles from the typing unit.

(2) Remove the typing unit in accordance with the section entitled "28 Typing Unit, Disassembly and Reassembly".

(3) Disconnect all plugs and receptacles from the perforator-transmitter base.

(4) Remove the mounting studs from each end of the electrical service unit.

(5) Remove the power control switch assembly bracket at the right end of the unit and the line-test-key control assembly at the left end.

(6) Remove various components from the electrical service unit by removing their mounting screws and disconnecting wire or cable connections as necessary.

(7) If it is desirable to remove the electrical service unit completely from the cabinet, disconnect the remaining wires and cables.

NOTE: On some sets it may be necessary to remove the perforator transmitter in order to remove completely the electrical service unit. If necessary, refer to the appropriate section for removing the equipment from the cabinet.

(b) With auxiliary equipment

NOTE: When Automatic Send-Receive Sets include an auxiliary typing reperforator, an electrical service unit is used in the lower compartment of the ASR cabinet. To disassemble these units, open the bottom compartment.

(1) Disconnect all plugs and receptacle connections between the electrical service unit and other components and from the cabinet terminal boards.

(2) Remove the studs securing it to the relay rack and lift unit out.

(3) Remove various components from the electrical service unit by removing their mounting screws and disconnecting wire and cable connections as necessary.

THE SIEMENS T100 TELEPRINTER

General

The Model 100 Teleprinter is a page-printer operating on the start-stop principle, its design conforming to all international conventions on telegraph apparatus.

All the non-printing functional keys which are not assigned a code combination of the telegraph alphabet, eg runout, answer-back, etc are located above and to the right of the keyboard.

Internal illumination of the teleprinter ensures convenient reading even under unfavourable lighting conditions.

The machine is made up of assemblies whose relative positions are fixed by limit stops. They are connected electrically by means of plug and clip connectors which enables easy detachment from each other.

Each assembly of the teleprinter is a self-contained functional unit which can be replaced without the necessity of readjusting the teleprinter. This design principle greatly facilitates maintenance and repair work. The teleprinter is also designed for the incorporation of a number of companion devices, eg reperforator and tape transmitter attachments, remote control unit etc and so can be easily adapted to any service conditions which may occur. Special teleprinter versions are available to satisfy specific service demands.

As far as the telegraph speed is concerned there are two variants of the teleprinter:

(*a*) Working at a telegraph speed of 50 bauds equalling a maximum typing speed of $6\frac{2}{3}$ characters/s (400 operations/min = 66wpm). Adaptation to different telegraph speeds of up to 75 bauds (10 characters/s = 600 operations/min = 100wpm) is possible.

(*b*) Working at a telegraph speed of 100 bauds equalling a maximum typing speed of $13\frac{1}{3}$ characters/s (800 operations/min = 133wpm). Conversion to lower telegraph speeds of, say, 75 bauds or 50 bauds is possible.

The page teleprinter is capable of producing about the same number of carbon copies as an ordinary office typewriter. The line spacing can be adjusted easily without tools to normal, $1\frac{1}{2}$ or double line spacing.

The type basket is supported in a carriage causing the platen with the paper to remain stationary while characters are typed and also while case shift takes place. The platen is only moved for line feed.

The teleprinter is normally fitted with an answer-back unit and designed for neutral (single) current operation. It can also be equipped for polar (double) current operation in which case the transmitter incorporates a second send contact and the receiver a relay converter.

The send contact and the motor are encapsulated to suppress radio interference frequencies and to avoid contamination.

The outgoing lines are provided with high-grade interference suppression equipment. The motor is provided with a fan to evacuate the heat generated inside the motor casing. The teleprinter therefore remains at a lower temperature and the lubricating properties of the oil used for maintenance will hardly deteriorate.

Practical operation has shown that the page-printer need only be lubricated at intervals of 1,000 maintenance units. With 50 bauds, these are equivalent to a maintenance interval of 1,000 operating hours. The number of maintenance units is visible from the outside through a counter window

OPERATING PRINCIPLE

When the teleprinter is turned on, the motor runs at its rated speed. The selector magnet is energized by closed-circuit current. The transmitter, receiver and printer shafts are in their rest positions.

Transmission Cycle

Upon depression of a key the associated code combination is set mechanically, the transmitter shaft being coupled with the continuously revolving drive shaft. The transmitter samples the code combination set during one revolution of the transmitter shaft.

The elements of the selected telegraph signal are sent to line in sequential form: first the start element (no-current period), then the five intelligence bearing elements (a characteristic combination of current pulses and no-current periods) and finally the 50 per cent prolonged stop element (current pulse). The transmitter shaft is now arrested mechanically.

Reception Cycle

The start element of an incoming telegraph signal causes the receiver camshaft to be coupled with the drive shaft. During its revolution the incoming five-unit telegraph signal is sampled electrically and transferred to mechanical setting members. Just before the receiver shaft is arrested by the stop element at the end of its revolution, it trips the printer which types the character defined by the mechanical setting or initiates the associated function (carriage return, line feed, etc). Most of the circuit modes used provide for a home record of the outgoing message to be produced via the receiver.

Detailed Functional Description

Keyboards

Meaning of symbols on function keys: In keyboard

A . . . letters shift

1 . . . figures shift

< carriage return

≡ line feed

✠ who are you? (tripping the distant answer-back unit)

🕭 bell

e code combinations 32 (five no-current periods) (since this signal is not permitted in international traffic, the associated key is normally locked).

The only unlettered key is the space bar. In the special function key assembly above the keyboard the following three keys are assigned in the basic version.

. . . . run-out

☆ here is (tripping one's own answer-back unit).

✶ on/off control of internal illumination. Unlettered keys are unassigned.

Constructional Layout

The Teleprinter 100 consists essentially of the following constructional units:

Mounting frame with keyboard
Receiver
Transmitter
Printer
Motor with governor
Bottom plate
Cover

Setting the Code Bars (Fig. 2.151)

When a key is being depressed, the corresponding code combination will be determined by the setting of five code bars 8 which are arranged across and below the key levers 5.

The code bars 8 have V-notches cut into their upper edges. When a key is being depressed, the respective key lever will glide along the inclined flanks of the teeth. Depending on the sense of inclination of a tooth, the code bar will be displaced endwise either to the right (current pulse) or the left (no-current period). The bellcranks 1, which are supported in the transmitter unit, engage in the code bars 8 and transfer their setting to the transmitter mechanism.

The position of the bellcranks 1 and, consequently, the position of the code bars 8 is secured during transmission by means of the cam-controlled locking bail 2. During this period no other key can be depressed (key lock).

When the function keys "A . . ." or "l . . ." are operated, a sixth code bar, the case shift locking bar 7, will be displaced in addition to the five code bars 8. Shifted to the left, it will lock all keys assigned to the figures side while all keys bearing letters will be blocked when this bar is shifted to the right (case shift lock).

The case shift position is secured by detent 6. Also situated below and across all key levers is the common start bail 4 which is moved downwards no matter which key is depressed. This bail commences the downward movement to a lever 3 whose upright arm engages the release lever of the transmitter.

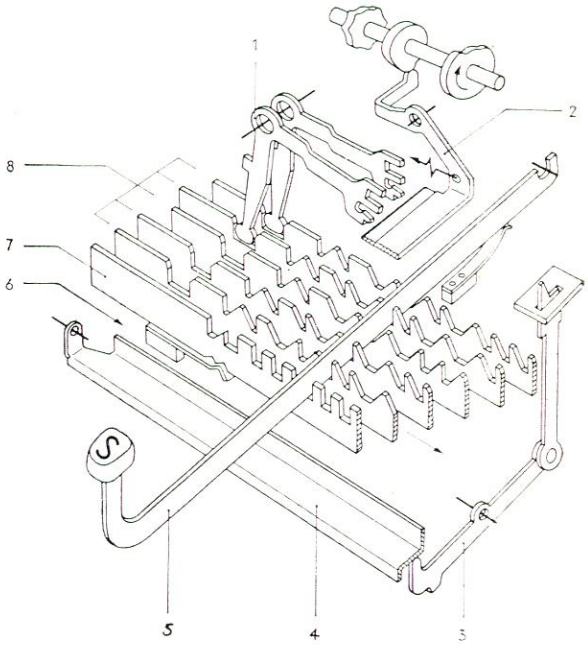


Fig 2.151. Setting the code bars.

Starting the Transmitter (Figs 2.152 and 2.153)

As already mentioned, depression of a key causes start bail 4 and 3 to move downwards so that the upright arm, pivoted to lever 3, will abut against release lever 11 whose arm will disengage locking lever 10 from release bail 9. The release bail 9 is pivoted under the action of a spring and its locking tip disengages from the clutch. Star wheel 12 is now free and is turned by pawl springs 14 and a further spring. The pawls engage in the internal serration 13 of the clutch drum. They are displaced by one third of a tooth pitch with relation to each other so that only one of the three pawls will actually engage and drive the drum. As a result, the maximum take-up delay cannot exceed a period corresponding to one-third of a tooth pitch.

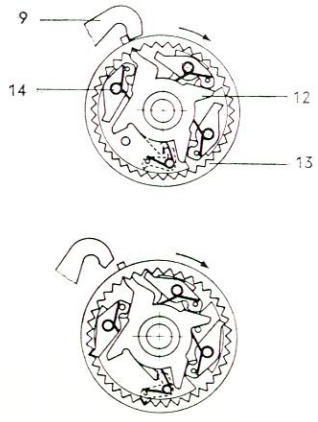


Fig 2.152. Three-pawl clutch.

Run-out Feature (Fig 2.153)

When a special function key ". . . ." is operated, bail 18 moves lever 16 to the rear. As the inclined face of lever 16 glides along guide 17, it is moved downwards and this motion is communicated to release lever 15 and locking lever 10. Release bail 9 is disengaged and the clutch is free to turn.

The signal last keyed will be transmitted in succession as long as the key " . . . " is held depressed.

Transmitting a Code Combination (Fig 2.154a)

The bellcranks 1 are in continuous engagement with code bars 8. They communicate the movements of the code bars 8 to the setting levers 24 which co-operate with the cam-controlled code levers 22.

Transmitting a Current Pulse (Fig 2.154a)

Code bar 8 has been shifted to the right and bellcrank 1

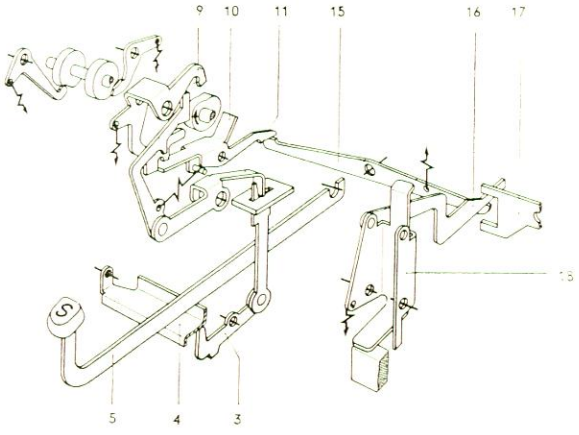


Fig 2.153. Starting the transmitter.

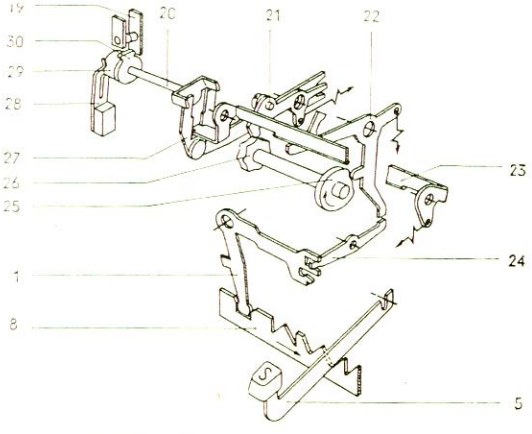


Fig 2.154a. Transmitting a current pulse.

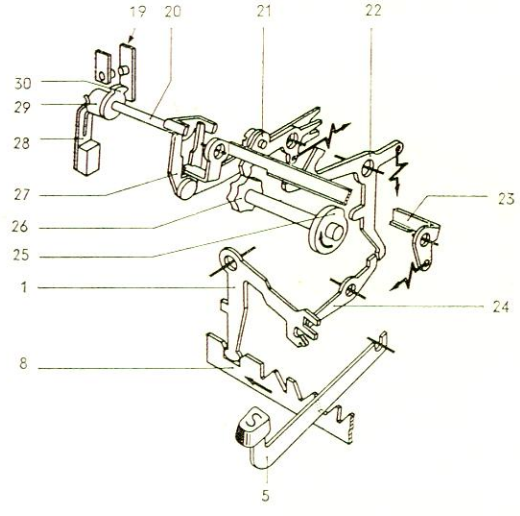


Fig 154b. Transmitting a no-current period.

has turned setting lever 24 so that the latter is unable to obstruct the movement of code lever 22. Code lever 22 follows the contour of cam 25 under the action of a spring and turns bail 23, which is held against lever 22, in a counter-clockwise sense. Rocker 27 is pivoted to lever 21 and is thereby displaced in a vertical plane by cam 26. As rocker 27 rises, its right prong hits against the right arm (seen from the rocker side) of switching shaft 20. Switching shaft 20 and its switching plate 30 are turned in a counter-clockwise sense, whereby contact 19 is closed.

Transmitting a No-current Period (Fig 2.154b)

Code bar 8 has been shifted to the left and bellcrank 1 has turned lever 24 so that it abuts against code lever 22. Code lever 22 is now prevented from following its cam 25. Bail 23 and rocker 27 are not shifted. When the cam-controlled lever 21 moves upwards, the left prong of rocker 27 hits against the left arm of switching shaft 20. Shaft 20 and its switching plate 30 are turned in a clockwise sense and contact 19 opens.

NOTE: If a current pulse is followed by another current pulse (or a non-current period is followed by another no-current period), rocker 27 will not meet with any resistance because switching shaft 20 is held in the position associated with the preceding pulse by friction brake 29 and spring 28.

Transmitting the Start Element and the Stop (Figs 2.154, a and b)

Transmission of the start pulse and of the stop pulse is independent of the position of the code bars.

One of the lobes on cam 26 causes rocker 27 to open contact 19 before the code combination proper is transmitted, thereby generating a no-current period (start element).

A sixth code letter, which is not faced by a setting lever, engages under the control of a cam after the five code levers assigned to the intelligence bearing pulses. Rocker 27 is set for the transmission of a current pulse and subsequently raised by another lobe on cam 26. Contact 19 is closed (stop element).

Stopping the Transmitter Shaft (Fig 2.155)

In the course of the revolution of the transmitter shaft, cam 33 returns release pawl 11 and release bail 9 into the normal position. Release lever 11 is turned so far that, even when the key is held depressed, locking lever 10 and release bail 9 will engage. This eliminates the possibility of double tripping. As a result of the momentum of the transmitter shaft, further increased by zero-setting lever 32, the shaft tends to continue its rotation while the star wheel is already locked. This will cause the clutch pawl to disengage from the internal serration of the clutch drum. The transmitter shaft is declutched and held by anti-bounce lever 31.

Selector Magnet Assembly

Applied to the selector magnet are two armatures that can be pivoted independently of each other. The larger of the two armatures has been provided for tripping the receiver camshaft while the smaller one is intended to sample the incoming five-unit code combination. Each

armature is under the action of a restoring spring. When the machine is switched on, current is flowing through the magnet winding and both armatures are held attracted.

Starting and Stopping the Receiver (Fig. 2.156)

The receiver shaft is driven by way of friction clutch 34. In the normal (rest) condition, the receiver camshaft 35 is arrested by locking lever 39 and release lever 41. When the start element arrives (no-current period), both armatures release. The start-stop armature 36 drops on to lever 40 which is thereby caused to disengage from locking lever 39 via release lever 41. Cam 38 is now able to pivot the locking lever 39 and the receiver camshaft is free to turn for one revolution. As the receiver shaft revolves, the crescent-shaped lever 40, raised by resetting cam 37, applies the start-stop armature 36 to the pole shoes of the magnet.

During the stop period the armature is held attracted by the magnet. Lever 40 returns into its rest position. At the end of the revolution of the receiver shaft the nose of cam 38 runs up against locking lever 39. The cam is now unable to push the locking lever aside and the receiver shaft 35 is thereby arrested.

Sampling the Five-unit Code Combination (Figs 2.157, 2.158 and 2.159)

Selector cam 46 offers armature 45 for each code element to magnet 44. When the magnet is energized at this instant (current pulse), armature 45 is held attracted while shaft 35 continues to turn. Selector lever 48 pivots in a clockwise sense as it rides down the lobe on cam 47. Selector lever 48 is able to follow the contour of cam 47. While the edge 48b of selector lever 48 swings upwards, code lever 42 is turned in a counter-clockwise sense by cam 43. The operating edge of selector lever 48 tips the sword 50 in a counter-clockwise sense. Selector lever 48 and code lever 42 are returned so that the sword is fixed in its position by guide 49.

If the magnet happens to be de-energized (no-current period) while the armature is being offered, armature 45 will ride down the cam lobe on cam 46.

When selector lever 48 is being turned by cam 47, its extension 48a abuts against the tip of armature 45. As code lever 42 is now turned in a counter-clockwise sense, sword 50 will be held by a spring at the right-hand side of the guide.

After the five code elements of the signal have been sensed, the code levers are released by their cams. The swords move upwards under the action of the code lever springs and set the transfer bars.

Rangefinder (Figs 2.160, 2.161 and 2.162)

The rangefinder serves mainly to measure the actual receive margin and, in certain cases, to ensure reliable reception of signals if the line exhibits heavy bias distortion.

The levers involved in the mechanical setting process are supported in a timing disc 52 and can be turned round camshaft 35 within a certain range. Since lever 40 has a crescent shape, the start-stop cycle remains unchanged, whereas the sampling instants are advanced or retarded according to the setting of timing disc 52. The scale, subdivided into 120 graduation marks each corresponding to one per cent of a pulse length, is provided with a pointer 53

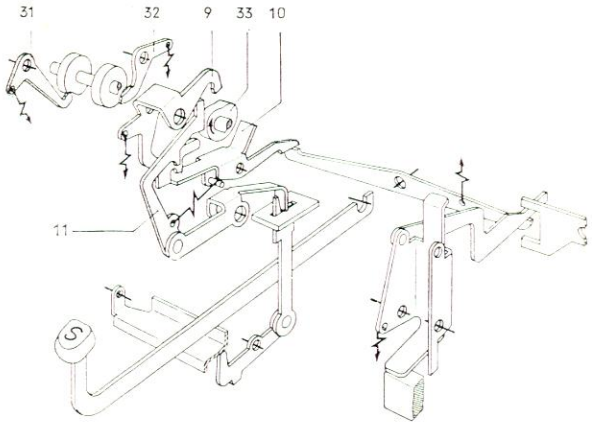


Fig 2.155. Stopping the transmitter shaft.

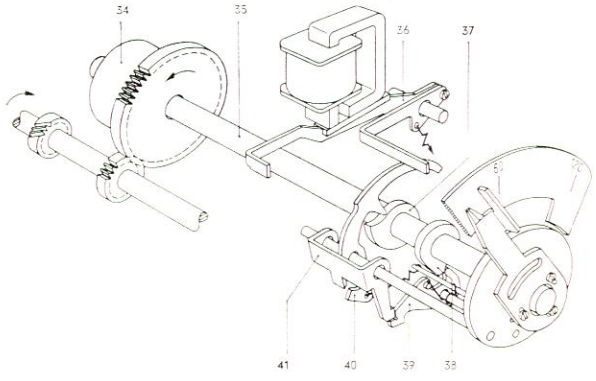


Fig 2.156. Starting and stopping the receiver shaft.

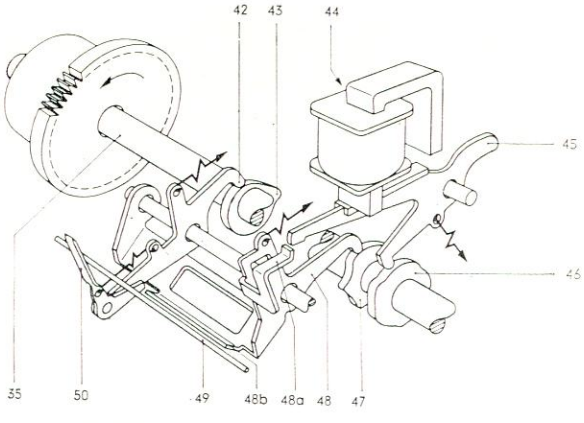


Fig 2.157. Sampling the five-unit code combination.

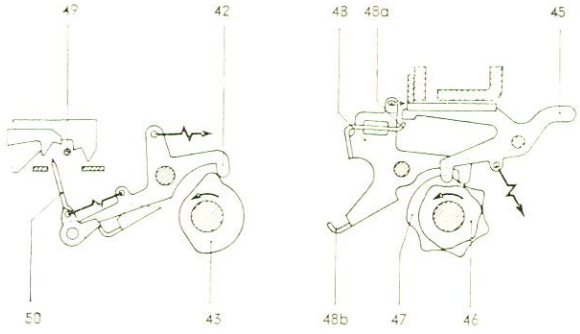


Fig 2.158. Sampling a current pulse.

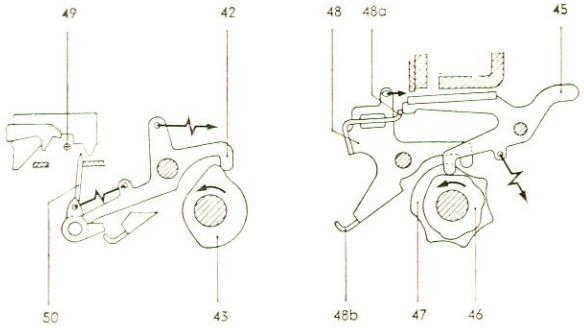


Fig 2.159. Sampling a no-current period.

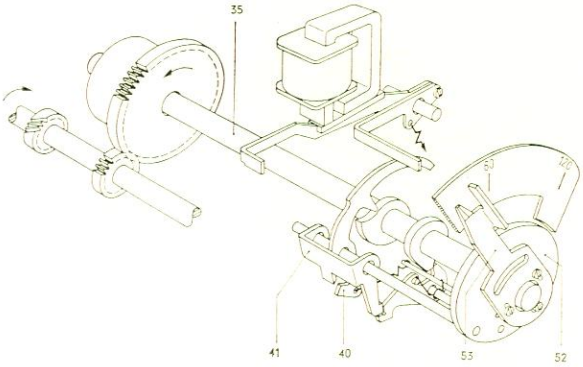


Fig 2.160. Function of range finder.

which indicates the amount of displacement to the one side or the other of the ideal sampling instant.

To measure the receive margin, the teleprinter is operated off line. The send contacts must be set for optimum signal formation.

Proceed by typing "R" and "Y" in alternate sequence and set the pointer of the rangefinder towards "O" until the limit of correct signal reception is reached. (**Fig 2.161** shows the current characteristic of an undistorted signal (Y)).

In position 2, the sampling instants lie just within the associated pulses and the pointer is on graduation mark 15. Repeat this measurement by shifting the pointer towards graduation mark 120 until the sampling instants are again just within the associated pulses. In example 3, the pointer is on graduation mark 105. The range within which the signals are correctly received is therefore 105 − 15 = 90 per cent. Now shift the pointer to graduation mark 60 (ie 105 + 15)/2, as shown at 1.

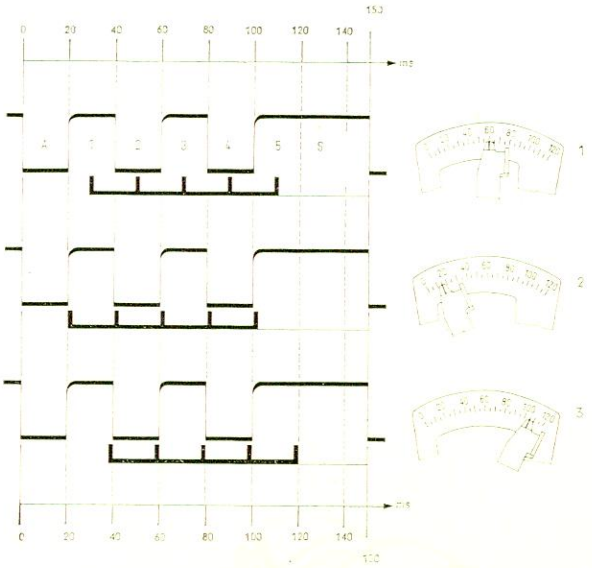


Fig 2.161. Signal Y undistorted.

If the machine is now operated on line, the arriving signals may have a start-stop distortion of up to ± 45 per cent without false signals being printed.

If a constant bias distortion is introduced on the line to which the machine is permanently connected, the rangefinder can be so adjusted as to ensure reliable reception.

As is evident from the following figures, the receive margin is determined in on-line operation (positions 1 and 2) and afterwards the pointer displaced in such a way that the distorted signals are sampled in the pulse centre (position 3).

PRINTER

Expanding Band Clutch (Fig 2.163)

After arresting lever 58 has disengaged, it rotates under the action of a spring, its locking nose releasing the clutch. Lever 296 rotates under the action of expanding band clutch

297 and of a spring (which is not visible in the figure). At the same time expanding band clutch 297 is pressed against clutch drum 298. The printer camshaft is now friction-coupled with the drive system. At the end of the revolution lever 58 runs up against locking nose 296a of the clutch. The movement of lever 296 with respect to the printer camshaft causes expanding band 297 to be contracted and to be disengaged.

The printer camshaft is now decoupled again.

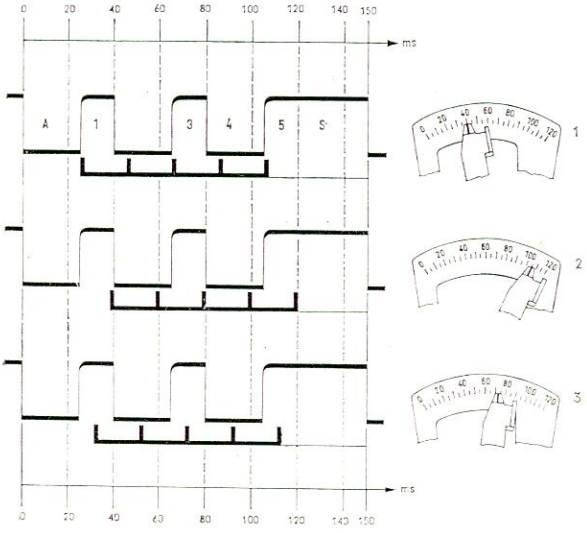


Fig 2.162. Signal Y distorted.

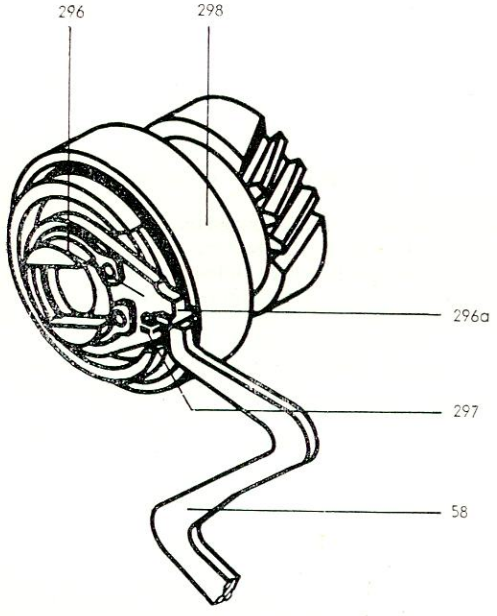


Fig 2.163. Expanding band clutch.

Starting and Stopping the Printer (Fig 2.164)

At the end of its cycle receiver shaft 35 causes printer shaft 59 to be released for one revolution. In the rest position of the printer shaft release lever 58 holds the expanding band of clutch 60 disengaged from the clutch drum. The other end of release lever 58 is in engagement with release lever 294 whose nose 294a lies between lever 55 and lever 56 of the receiver. The two levers are interconnected by means of a spring. Another spring causes lever 58 to abut against stop 57, ensuring that lever 58 remains in engagement with lever 294. Under the control of cam 54, the arm of lever 55 moves upwards. After having reached the uppermost position just before the receiver shaft is arrested, lever 55 is released, striking against release lever 294. Release lever 294 disengages from release lever 58 which unlatches nose 296a of the expanding band clutch. The expanding band can now engage with the clutch drum and drive printer camshaft 59 through frictional force.

In the last quarter of the printer camshaft revolution, lever 295 controlled by cam 292 now presses, via clamping lever 293, release lever 58 into the operating range of locking nose 296a until it comes to rest against stop 57. Lever 294 engages again with release lever 58. At the end of the revolution clamping lever 293 is forced out of engagement again and locking nose 296a runs up against release lever 58. As described previously expanding band 60 is forced out of engagement with the drum, and the camshaft is decoupled again.

Setting the Code Bars (Fig 2.165)

Transfer bar 63 can be moved vertically. When a no-current period arrives, the tip of sword 50 hits into the notch in transfer bar 63 whereby the bar is lifted. This causes the code bar 66 to be shifted to the left by the levers 64 and 67. The code bar is secured in this position by detent 65. At the same time code segment 61 is turned in a counter-clockwise sense by way of bellcrank 62.

With a current pulse, the code bars and code segments are shifted in the opposite sense.

The five code segments 61 as well as the five code bars 66 are provided with rectangular notches on their upper edges.

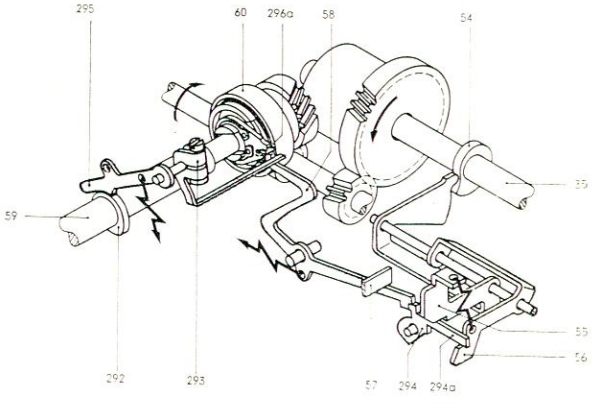


Fig 2.164. Starting and stopping the printer.

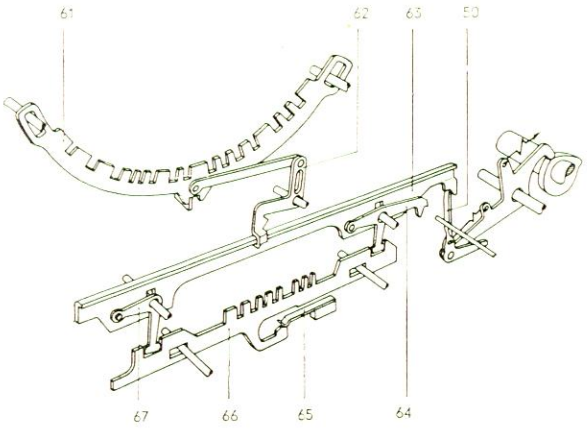


Fig 2.165. Setting the code bars.

An alignment of notches will be formed which allows one of the pull bars (the one assigned to the received signal) to engage while the remaining bars are blocked.

Printer Shaft (Fig 2.166)

The printer shaft controls all functions of the printer. Backward rotation of the printer shaft is prevented by anti-bounce lever 76 and a zero-setting lever pushes the camshaft into the rest position.

Type Basket Carriage (Fig 2.167)

The type basket carriage glides with its rollers 79 and 80 on the supporting rail 78 which is installed in the printer frame. With its roller 83 it is braced against rail 81. The axles 82 and 87 take the five code segments and, where necessary, a locking segment (only one segment 61 is shown in the drawing). These two axles serve also as guides for the pusher.

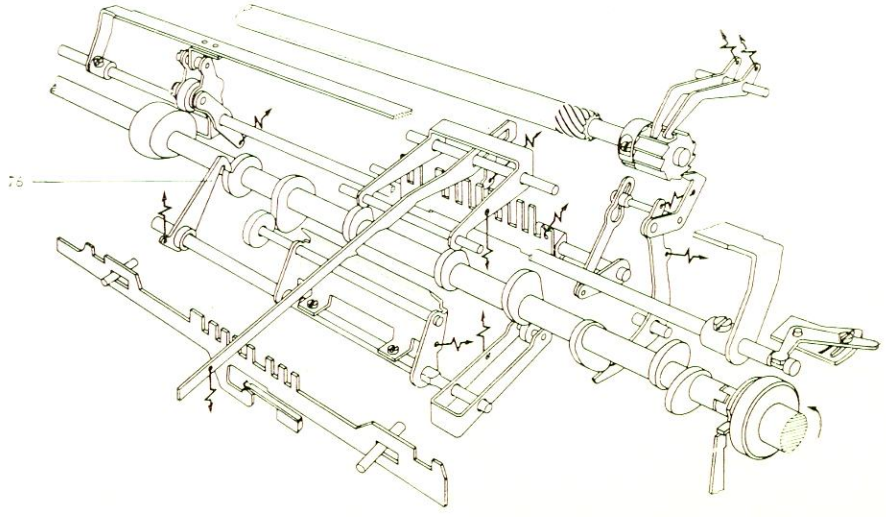
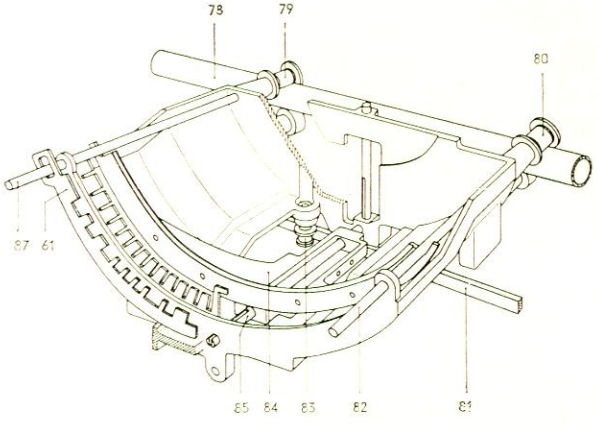


Fig 2.166. Camshaft of printer.

Fig 167. Type basket carriage.



Pusher 84 glides to and fro on axle 85 when printing occurs. Pull bars and type bars are supported in a type bar segment.

Printing (Figs 2.168 and 2.169)

Pushers 84 raises the pull bars 88 so that the code segment 61 can be displaced freely. As the printer bail 89, controlled by cam 77 and roller 72, moves to the front, it takes with it the pusher 84 gliding on axle 85. A pull bar 88 is now able to drop into alignment notches in the code segments 61. On its way forward, the pusher will now catch the engaged pull bar 88. Type bar 90 is geared to the pull bar so that it will be driven about two-thirds of its travel and then fly up to the point of impact on the platen.

The type bar racking force can be adapted to the required number of carbon copies. The operating surface of cam 77 is not straight but cone-shaped so that it rises from the right to the left. Roller 92 can be displaced across operating sur-

face of cam 77 by means of adjusting lever 91 and axle 93 and the type bar rocking force is correspondingly increased or decreased.

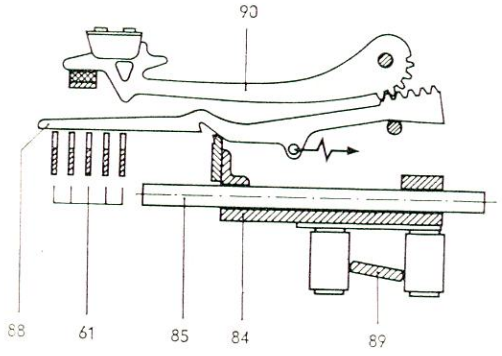


Fig 2.168. Printing process.

Raising and Lowering the Ink Ribbon (Fig 2.170)

Normally, the ink ribbon is positioned below the line of print. Raising and lowering of the ink ribbon 94 are controlled by the pusher 84 by way of the bracket 98.

When the printer shaft begins to revolve, pusher 84 transfers its forward movement to ribbon lifter 95 by means of bar 97, bellcrank 99 and push rod 96. The ink ribbon 94 is being raised. When pusher 84 returns, all of the aforementioned motions are reversed and the ink ribbon is lowered again.

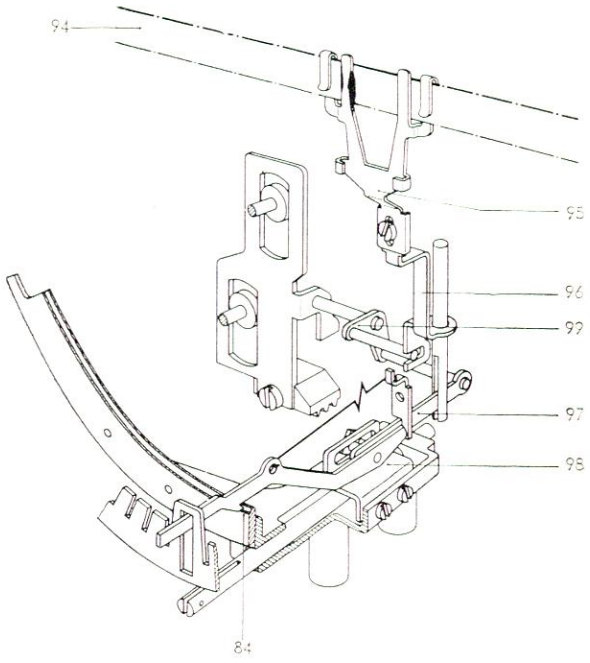


Fig 2.170. Raising and lowering the ink ribbon.

Type Basket Carriage Feed (Figs 2.171 and 2.172)

When a signal has been printed, the carriage is fed along by one character space.

Cam 71 controls lever 105 which turns ratchet 103 and, with it, the feed screw 100 by way of feed pawl 104. Detent 101 and zero-setting lever 102 fix the position of feed screw 100.

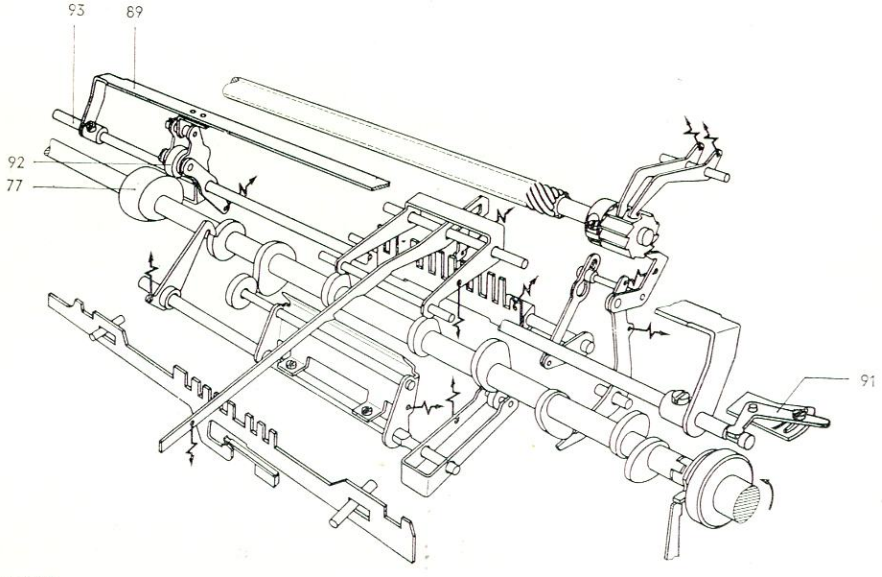
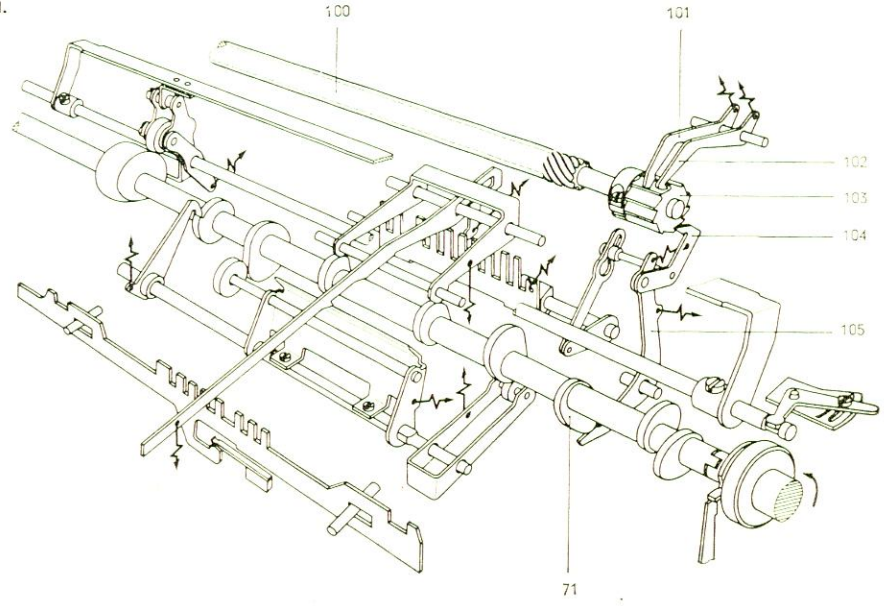


Fig 2.169. Adjusting the type bar rocking force.

Fig 2.171. Type basket carriage feed.



Feed rack frame 107 is mounted on the type basket carriage. Its sliding block 108 engages in the threads of feed screw 100. Sliding block 108 is held in engagement under the pressure of bar 106. Each time the feed screw 100 is advanced, feed rack frame 107 and, consequently, the type basket carriage is moved.

When the type basket carriage has reached the end of a line, sliding block 108 leaves the threaded portion of feed screw 100 and moves onto its smooth end. Carriage feed is stopped and blocked.

Bell Signal at the End of the Line (Fig 2.173)

After 59 carriage steps a bell is sounded to indicate the end of the line. Bracket 109, screwed onto the type basket carriage, hits against an arm of bail 110. Bail 110 is pivoted on its axle and its lug 110a engages tapper 111. With the next carriage feed operations tapper 111 glides along the slanted face 112a of stop plate 112. Tapper 111 is displaced axially, disengages from lug 110a, and strikes against the bell dome.

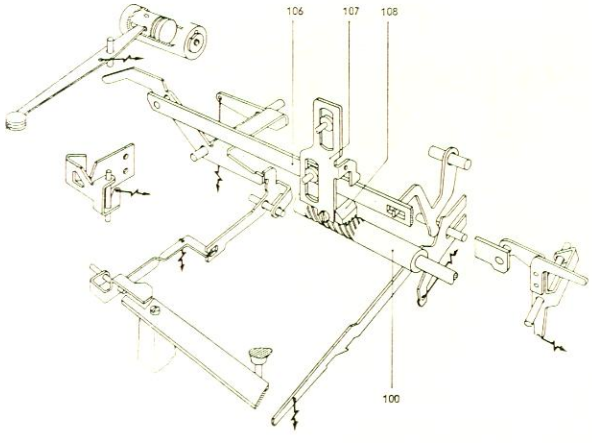


Fig 2.172. Type basket carriage return.

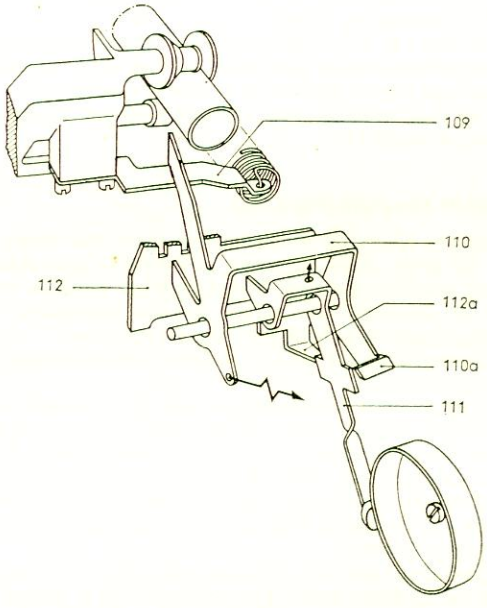


Fig 2.173. Bell signal at the end of the line.

Interpretation of Function Signals (Figs 2.174 and 2.175)

Up to 10 different function pull bars may be arranged below the transfer bars. Counting from left to right the pull bars are assigned to:

1. Figures shift — 1 . . .
2. Letters shift — A . . .
3. Requesting the answer-back code (who are you?) — ✠
4. Figures side F
5. Figures side G
6. Figures side H

(4–6: not included in the basic version)

7. Bell — ◁
8. Code combination 32 — ⊖
9. Carriage return — ◁
10. Line feed — ≡

In the normal condition all pull bars 115 (only one is shown in the drawing) rest on axle 113a of bail 113. In its position the pull bars do not obstruct movement of the code bars 66. When the printer shaft has started to revolve, bail 113 glides down the lobe of the cams 68 and all pull bars 115 are now placed onto the code bars 66. If one of the pull bars finds an alignment of notches in the code bars 66, it will drop and engage. Following the contour of cam 74, bail 114 swings to the front. It will catch the engaged pull bar and initiate the function associated with this bar.

As the printer shaft continues to revolve, bail 114 is returned. Pull bar 115 is retracted under the action of a spring and will finally glide along on axle 113a. Pull bar 115 has meanwhile disengaged from bail 114 and is fully retracted by the spring.

Each function can be performed with or without carriage feed, as may be desired. Carriage feed can be suppressed in the following manner:

Each pull bar 115 has a downward extension at its end which is positioned opposite a tooth of spring-loaded comb 118. When a pull bar 115 is drawn, its extension pivots comb 118. This motion is communicated to feed pawl 104 via axle 116 and bar 117. The feed pawl is thereby disengaged from the ratchet and the type basket carriage is not advanced.

If carriage feed is desired in connection with a function signal, all that has to be done is breaking out the corresponding tooth of comb 118.

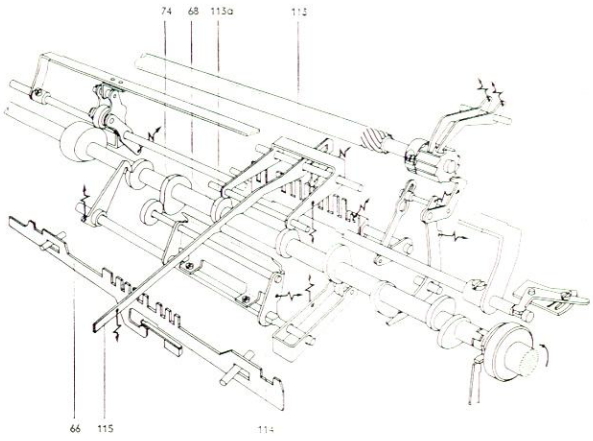


Fig 2.174. Interpretation of function signals.

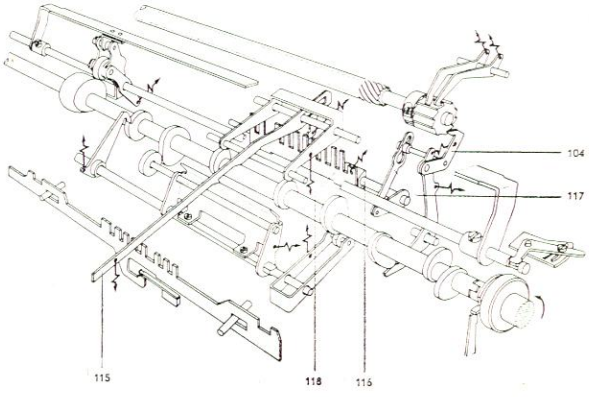


Fig 2.175. Suppression of carriage feed function.

Case Shift Function (Fig 2.176)

Each type head (pallet) carries two types, one above the other. To bring either the upper or the lower type into the printing position, the type basket carriage must be either raised or lowered. The platen remains stationary. The illustrated position is the upper (figures) position.

After depressing key "A . . .", pull bar 123 will engage and be drawn forward.

This movement is transferred to rack 120. This rack turns, by means of a gear, shaft 121 and the eccentric 128 in a counter-clockwise sense. Fork 119, screwed onto bail 122, follows eccentric 128. Since the tubular supporting rail 78 (on which the type basket carriage glides with its rollers) and bail 122 are rigidly interconnected, the rail and the carriage will be lowered.

Depression of key "1 . . ." causes pull bar 124 to turn rack 120 in the opposite sense. The eccentric 128 is turned in a clockwise sense and the type basket carriage is raised.

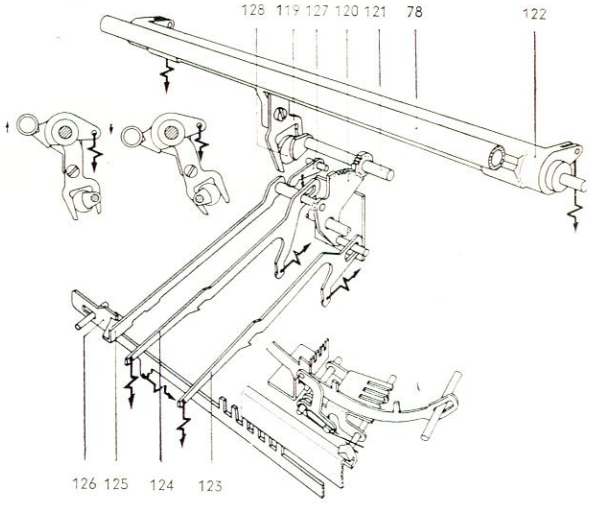


Fig 2.176. Raising and lowering the type basket carriage.

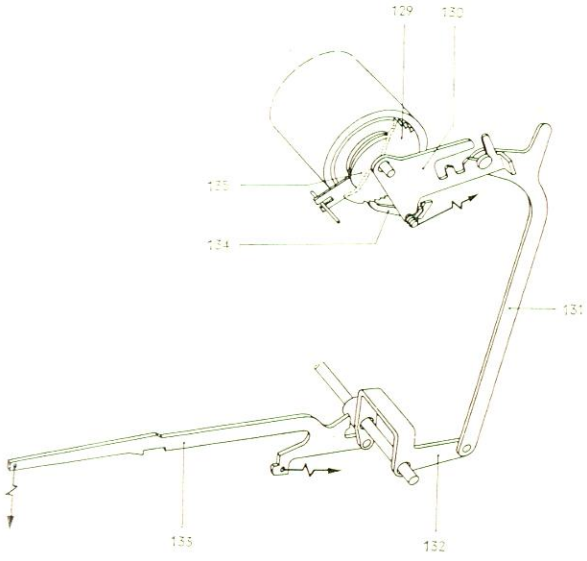


Fig 2.177. Line feed.

The weight of the type basket carriage is almost fully compensated by springs. A detent 127 secures rack 120 in its two end positions.

The case shift locking bar 126 is also illustrated in the figures position where it will block operation of all-function pull bars which are assigned exclusively to the letters side.

When shifting into the letters position, pull bar 125 is drawn to the rear by pull bar 123 and rack 120. A tension spring forces case shift locking bar 126 along the oblique face of pull bar 125 so that it is shifted to the right. In this position it will block all function pull bars assigned exclusively to the figures side.

Line Feed (Fig 2.177)

Pull bar 133 has been provided for the line feed function. It turns bail 132 so that rod 131 is pulled downwards. Rod 131 communicates this motion to lever 130 and its pawl 134. The latter engages in ratchet 129 and turns the platen. After line feed, pull bar 133 and the other parts are returned by a spring. Pawl 134 follows this movement and engages again 2 teeth later.

To adapt the machine to $1\frac{1}{2}$ or double line spacing, the pin on rod 131 must be inserted into the corresponding notch of lever 130 so that pawl 134 will step the ratchet by three teeth and four teeth, respectively.

A fricton brake 135 has been provided to hold the platen after each line feed operation.

Carriage Return (Fig 2.178)

To initiate the carriage return function, pull bar 138 has been provided. It turns lever 136 which raises bar 106. The latter lifts feed rack frame 107 clear of the feed screw 100. Lever 144 is turned at the same time and held by latching lever 140. This is to ensure that the type basket carriage can be returned by its spring without any obstruction into the beginning-of-line position. Stop 143 of the type basket carriage runs up against brake lever 145 whose other end is connected to the piston of the shock absorber. Just before the type basket carriage has been fully returned, pin 139 will strike against lever 141.

The latter is turned and latching lever 140 disengages from lever 144. Bar 106 is pulled downwards by a spring and

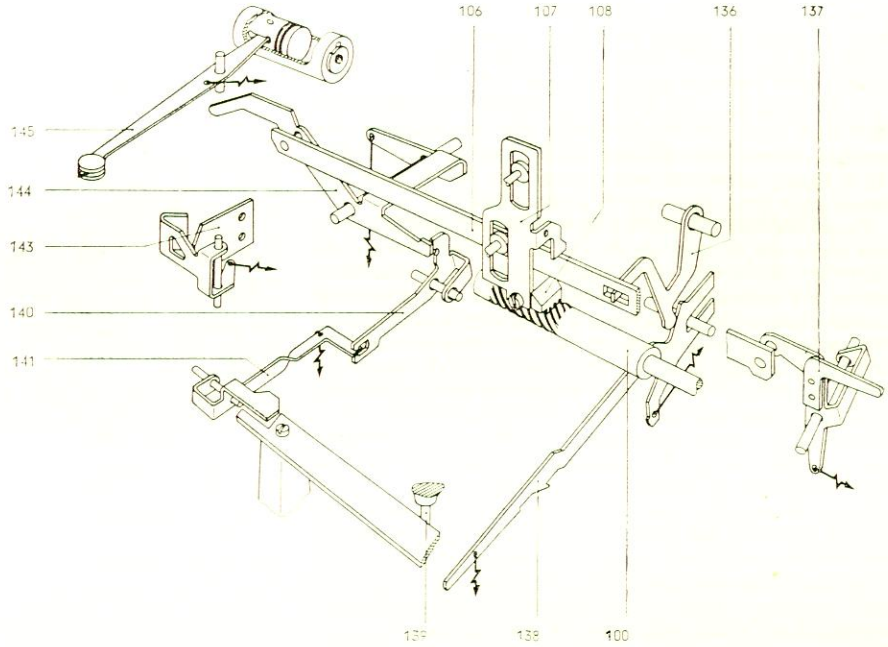


Fig 2.178. Carriage return.

sliding block 108 is again in engagement with the threaded portion of feed screw 100.

The hook-shaped part of stop 143 has gripped brake lever 145 in the meantime. After the carriage has been fed by a few character spaces, the hook-shaped part returns brake lever 145 to its normal position and releases it.

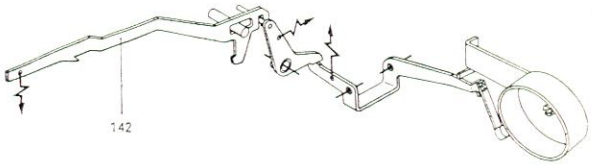


Fig 2.179. Bell

Bell Signal (Fig 2.179)

When the code combination for the bell signal "$\bar{Q}$" has been received, function pull bar 142 will come into action. The tapper is pulled away from the bell dome by way of a bellcrank. When pull bar 142 returns, the tapper strikes against the bell dome under the action of a spring.

Answer-back Unit (Distant Machine) (Fig 2.180)

When the code combination "$\ddagger$" (who are you) arrives, pull bar 153 is operated by function bail 114. A lug of this pull bar hits against extension 154a of lever 154 which is thereby turned to the front. This motion is transferred by lever 152 to lever 151 which is pivoted in a clockwise sense. The latter is rigidly connected with lever 146 by an axle. When lever 146 is turned, bail 155 will shift the five code bars 8 to the "current" position. Bellcranks 1 move setting levers 24 out of the reach of code levers 22. Now it is only the code combs 150 of the answer-back drum which determine whether a current pulse or a no-current period will be transmitted. During the revolution, code levers 22 will either rest against a tooth of code comb 150 (no-current) or follow the contour of their cams when the respective tooth has been broken out (current). The send contact is thereby controlled in the same manner as during keyboard transmission.

Since the code bars 8 are shifted into the "current" position, the transmitter is tripped by lever 151 abutting against locking lever 10.

To ensure that lever 151 remains in this position while the answer-back drum runs down, the upper arm of lever 146 leaves the notch in control disc 147 and rides on its periphery. A small locking lever is pulled into the notch by a spring to prevent lever 146 from engaging again.

At the same time, the lower arm of lever 146 releases the lever with pawl 149 which, during the revolution of the camshaft, drops below the next tooth in ratchet 148. Ratchet 148 is rigidly connected with control disc 147. It turns the answer-back drum by means of a driver pin.

The answer-back drum has 18 slots cut into the periphery into which the 18 code combs 150 are inserted. Each code comb has five teeth. Each tooth produces a no-current period. If a current pulse is desired, the corresponding tooth must be broken out. The combs which have been coded in this way are sensed consecutively by the five code levers 22. The first signal coming up for transmission is the code combination "letters shift" (five current pulses) because at this moment the answer-back drum is still in the rest position and no code comb is in front of the code levers. When this first signal has been transmitted, the cam-controlled feed pawl 149 will advance the answer-back drum by one step.

When the nineteenth signal has been transmitted, the upper arm of lever 146 can again drop into the notch in control disc 147. Keyboard lock, stepping of answer-back drum, and tripping of transmitter are thereby cancelled. The transmitter shaft performs another revolution—transmitting the code combination "letters shift"—and is then arrested.

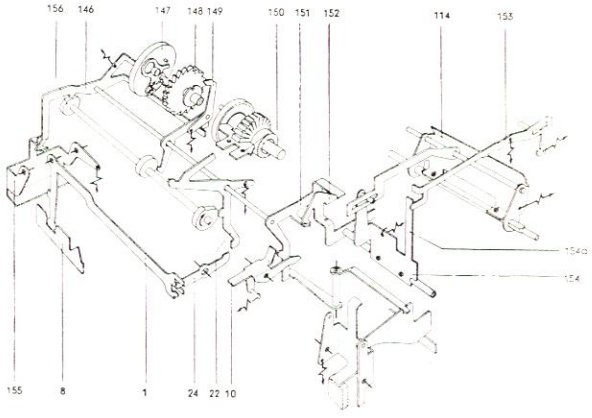


Fig 2.180. Tripping answer-back unit in distant machine.

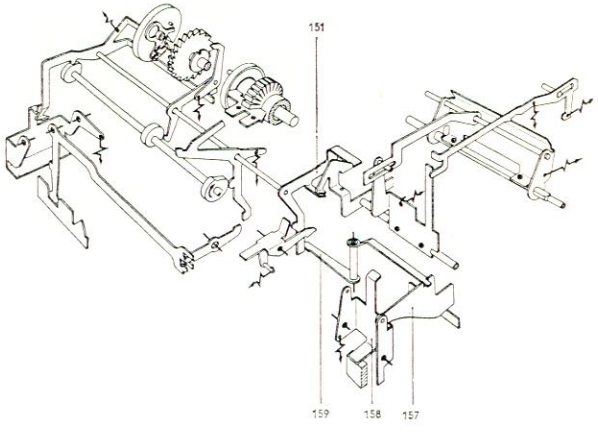


Fig 2.181. Tripping answer-back unit in home machine.

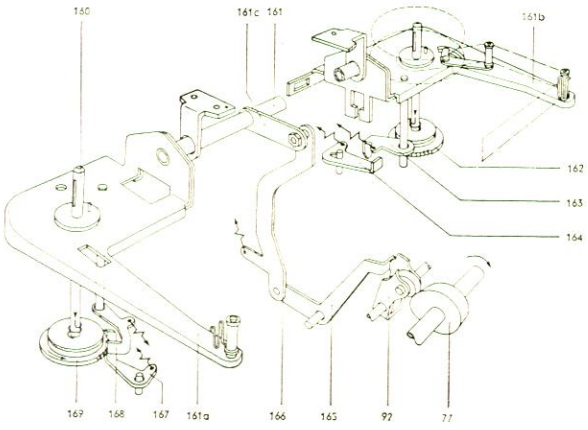


Fig 2.182. Ink ribbon feed.

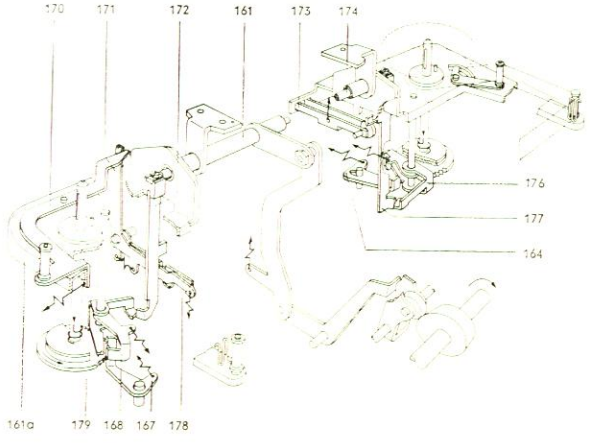


Fig 2.183. Reversing the direction of ribbon feed.

With most of the common circuit options the sending machine would also receive the transmitted code combination "✠" (who are you) so that the answer-back drum of the home machine would also run down and not only that of the distant machine. This is prevented in the following manner:

During keyboard transmission, the ear of lever 146 rides on cam 156. This cam is so shaped that, in the course of one revolution, levers 146 and 151 will be slightly turned to a point where lever 152 is disengaged so that extension 154a is positioned behind the bent end of pull bar 153. As a result, pull bar 153 will not meet any resistance.

The bar connected to bail 114 returns lever 154, and lever 151 engages again in its rest position.

Tripping One's Own Answer-back Unit (Fig 2.181)

The "answer-back" unit of the home machine is tripped by operating the special function key "☆" (here is). Bail 158 is forced to the rear. Shift plate 157 turns lever 159 so that lever 151 is pivoted. The transmitter and the answer-back unit are thereby tripped as described in the preceding sections.

Ink Ribbon Feed (Fig 2.182)

Ribbon feed is controlled by cam 77 and bail with roller 92. Hollow shaft 161 is rigidly connected to shift arms 161a and 161b. Ribbon spool shaft 160 and the shaft of detent 168 are supported in shift arm 161a while the feed pawl 167 is mounted in the printer frame.

When the hollow shaft 161 is turned (in a counter-clockwise sense) by cam 77, lever 165, shift bar 166 and lever 161c, all parts connected to the hollow shaft will perform the same movement. Ratchet 169 will swing towards and strike against feed pawl 167 which is supported in the printer frame. Running up against this pawl, the ratchet is turned and with it axle 160 on which the ribbon spool is mounted so that the ribbon is fed along. Detent 168 secures the position of ratchet 169 after every feed operation.

Reversing the Direction of Ribbon Feed (Fig 2.183)

Levers 177 and 172 are rigidly linked together. Both are secured in their proper position by detent 173. The lower end of lever 177 keeps the feed pawl and the detent pawl clear of the ratchet teeth.

When the ink ribbon becomes taut, it will turn reversing lever 170 in a counter-clockwise sense. This motion is communicated through lever 171 to lever 178. Lever 178 swings upwards and its notch engages the nose on reversing bar 172. When the hollow shaft 161 is turned as described in the section "ink ribbon feed" and the shift arm 161a is tilted, reversing bar 172 cannot follow this movement as it is held arrested in the notch of lever 178. Since the reversing bar 172 is rigidly connected with bar 177 through axle 174, bar 177 is also prevented from being tilted.

When the hollow shaft 161 turns the arresting roller supported in bail 173 snaps over onto the other side of the nose of bar 177. Reversing bar 172 applies pressure onto the one arm of lever 179. The other arm of lever 179 disengages detent 168 and feed pawl 167 from the ratchet. Bar 177 turns lever 167 so that the feed pawl 164 is allowed to engage in the ratchet. The direction of ribbon feed is thereby reversed. When the ink ribbon becomes again taut, the arresting roller will snap back into the other position and the above process will take place in the opposite sense.

DRIVE SYSTEM AND SPEED CONTROL

The teleprinter can be driven by a commutator motor with speed governor or by a synchronous motor. The power draw is approximately 70W. The governor incorporates a contact lever which is controlled by centrifugal force and a counter-acting spring. If the motor runs at proper speed, these two forces are balanced, and the contact makes and breaks at such a high rate that the motor adjusts itself to the rated speed without appreciable fluctuations.

The rated speed is checked with the aid of a 125cps tuning fork and the stroboscopic pattern on the governor cap. This pattern is observed through the vibrating shutter of the tuning fork. When the speed is correct, the stroboscopic pattern appears to be stationary.

During operation the speed can be checked by watching another stroboscopic pattern which is applied near the motor pinion.

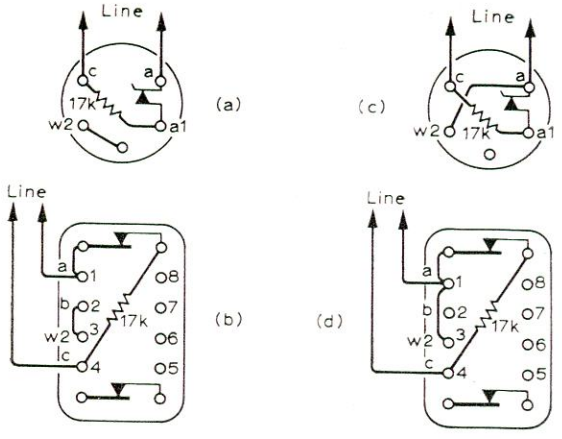


Fig 2.185. Siemens T100 teleprinter, plug wiring.

Fig 2.185a. Wiring for complete teleprinter, five-point plug.
Fig 2.185b. Wiring for complete teleprinter, eight-point plug.
Fig 2.185c. Wiring for receive only teleprinter, five-point plug.
Fig 2.185d. Wiring for receive only teleprinter, eight-point plug.

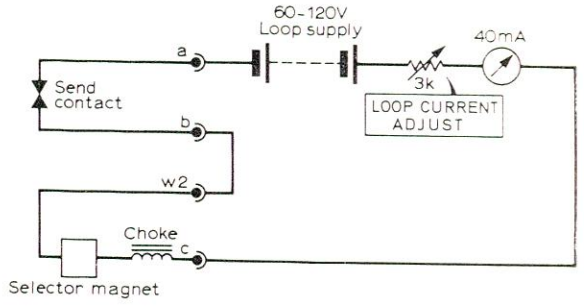


Fig 2.184. Siemens T100 teleprinter, external connections, two wire neutral operation.

Teleprinter Wiring Detail:

ABOVE: SIEMENS TYPE T100 (see pages 2.109/121)
BELOW AND RIGHT: AMERICAN TT4

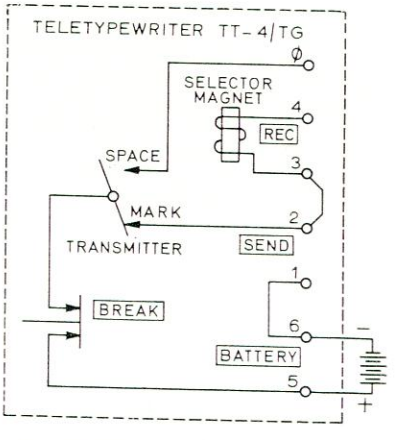


Fig 2.187. TT-4 teleprinter, signal wiring.

TELETYPEWRITERS TT-4/TG and TT-4A/TG

The two machines are basically the same; the 4A differs from the 4 as follows:

The unshift-on-space feature has been eliminated.*
The line feed may be adjusted for single or double line spaces.
The keyboard transmitter is improved.
The method of suppressing radio interference is simplified.
The carriage feeding and carriage return mechanisms are improved.
A new selector cage assembly is supplied to insure stability of the code rings.
The platen supporting bracket and the platen knob are changed.

The TT4 and TT4A are standard American communications, page-printing machines weighing approximately 40lb only.

They are supplied normally with gears for 45·5 bauds; other gears were available for 50 and 75 bauds.

Although intended primarily for single-current working, provision is made in the sending mechanism for double-current working but an external polar relay is required for receiving double current signals.

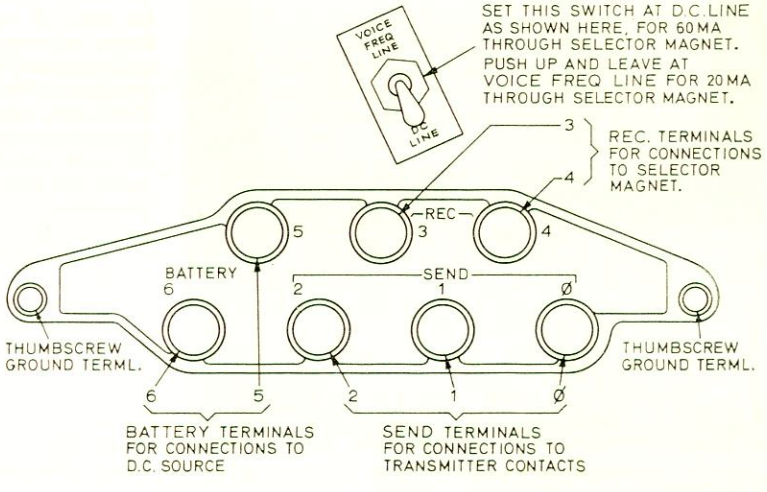
Provision is made for locking the keyboard, type bar carriage and platen for transporting. These locks are located respectively at right-hand end of keyboard, left-hand end of carriage (which must be moved to the extreme left-hand position), and right-hand end of platen (which should be shifted to FIGS position before locking).

A switch marked VOICE FREQ LINE/DCL LINE, located on the left side under the dust cover, enables the receiving magnet to operate at 20mA or 60mA respectively at 115V dc.

The universal motor will operate on 105 to 125V dc or ac 50 to 60cps; the consumption is approximately 150W. The motor speed is maintained at 3,600rpm by an adjustable electrical governor with a stroboscope which requires a tuning fork at 180vps. Motor power is applied through a switch at the right hand end of the keyboard. The switch is turned to ON to start the machine and is turned OFF only to shut down the equipment completely. To place the machine in stand-by condition, the motor power is disconnected through a motor stop relay by shifting to FIGS and pressing the H key (STOP). The motor can be returned to operation when the BREAK switch is pressed.

General view of the TT4 teleprinter.

* It is possible to eliminate this feature on the TT4.



Fig, 2.186. TT-4 teleprinter signal connections.

On the TT4 teleprinter the switch for voice frequency line or dc line is positioned on the left hand side of the machine under the dust cover. The 7-way terminal board for line connections, shown here, is situated at the lower left hand side of the machine.

The following controls are available on a panel directly above the keyboard:

Line increase rheostat and a dc milliammeter for adjustment of line current.

Armature for adjustment of spring tension on the selector magnet.

Range (orientation) to align the cycling of the receiver selector cams with the midpoints of the spacing and marking intervals.

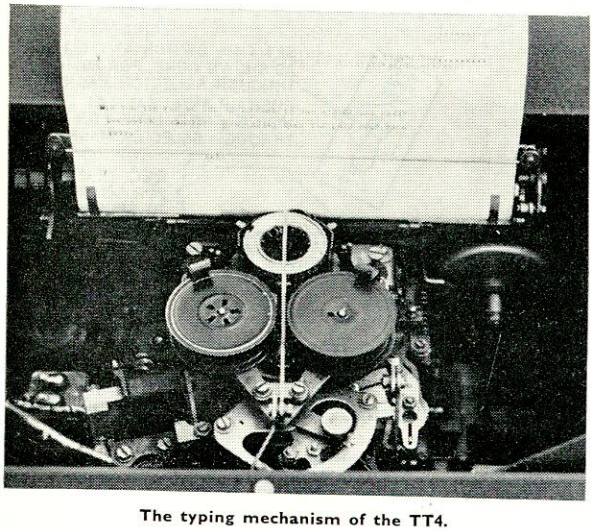
Light to illuminate control panel and motor governor adjustment.

Line fuse 125mA.

Motor fuse 1·6A 250V.

A seven way terminal board for line connections is situated at the lower left side of the machine.

The TT4 in a different case from that shown on p 2.123.



The typing mechanism of the TT4.

THE CREED MODEL 54 TELEPRINTER

The Model 54 Teleprinter was introduced by Creed and Co Ltd in 1954 and may be considered as a highly developed Model 7B with overlap camshaft and two colour printing. The keyboard, which resembles that of the Model 47, can be supplied in either a three-row or four-row version, with and without perforating attachment. It is in the keyboard and associated units that the main differences lie, and therefore these will be described. A section of general machine adjustments is included although no diagrams are given as these are generally similar to those of the Model 7B.

Transmitting Unit

This unit of the teleprinter is of a different design from that of the teleprinter No. 3 and 7. It comprises three units.

1. Keyboard unit.
2. Transmitting unit.
3. The answer-back unit.

The transmitter and the answer-back units are located at the rear of the keyboard.

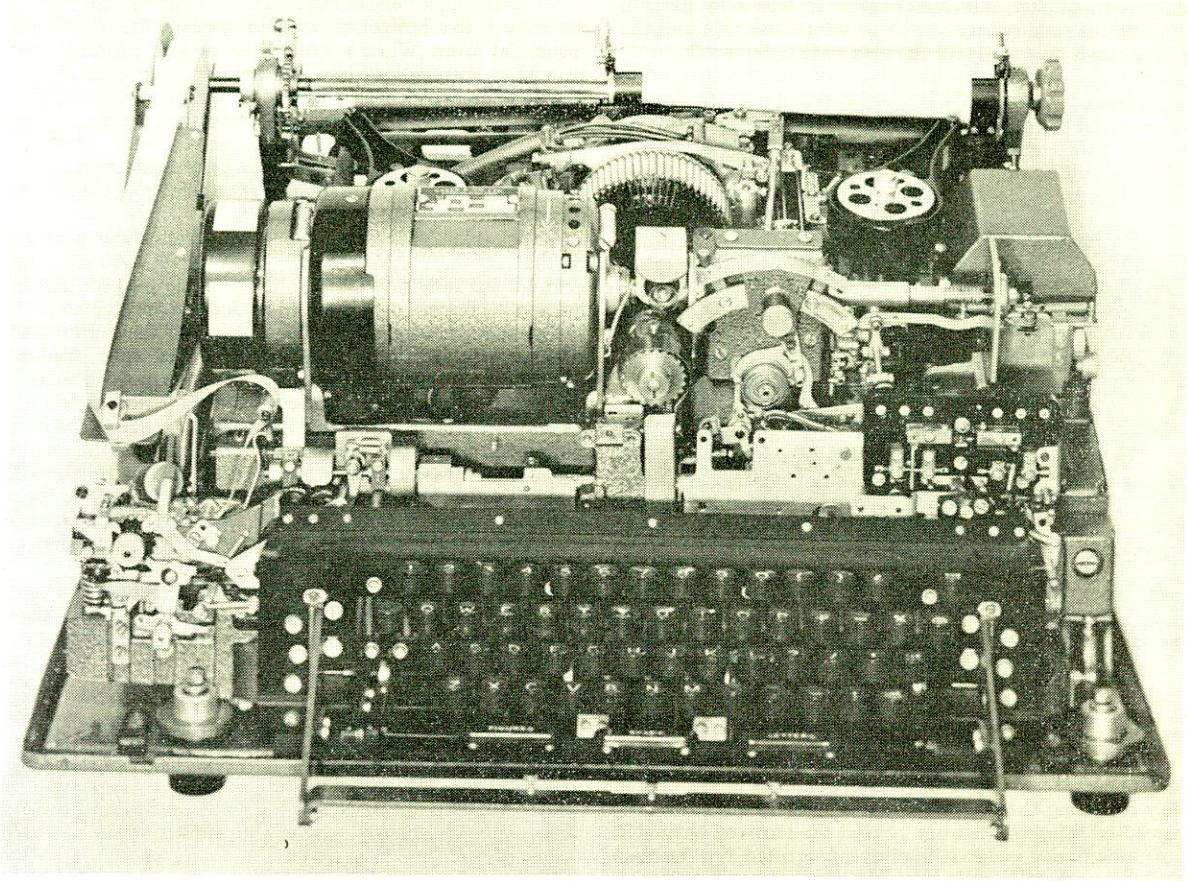
The above units are modified units of the teleprinter No. 47, which was first produced in 1947 as a tape printer to replace the 3X, and as such can be considered identical in operation except for detail differences.

The most common keyboard has three rows of keys and utilizes combination bars of the saw-tooth type, operated directly by the depression of the key bars and not as per the teleprinter No. 7, which relied on the transmitting cam to operate the combination bars. These combination bars move to the left for a space and to the right for a mark. The bars are numbered from the back of the machine to the front. With saw-tooth type combination bars it is unnecessary to provide for special arrangements to prevent the operation of two or more characters being sent at the same time, because when the bars are locked by a frame on the transmitting unit the projections on the combination bars prevent the operation of any other key bar.

Selection and Transmitting of a Character

When a key bar is depressed (R), the knife edge of the key bar strikes against a saw-tooth on the trip bar moving it to the left, this rotates the trip lever clockwise making the detent operating lever rotate anti-clockwise, this engages with the detent release latch, which rotates anti-clockwise, lifting the detent out of engagement with the clutch ratchet. The clutch ratchet is then forced by a spring into the engagement with the driving ratchet, causing the cam shaft to rotate in a clockwise direction. When the cam starts to rotate, the first lever to operate is the retention lever. This lever rises out of its indentation in the cam, and at the same time making the send/receive switch operating lever move to the left, moving with it the send/receive switch blade over to the left-hand contact (send).

Now that the s/r switch has operated the start element can next be sent. The start/stop selecting lever rides into its cam, rotating clockwise, slowing the striker positioning lever to follow it, in a clockwise motion. As the striker is pivoted from the striker positioning lever and held in a horizontal position by the striker guide, the striker moves to the left-hand side of the transmitter tongue. The striker lever rides off the node of the transmitter timing cam, rotating anti-clockwise, the



A general view of the Creed Model 54 teleprinter.

striker hitting against the left hand side of the tongue, sending it over to the space contact, giving the 20ms start signal.

The next element to be transferred is also a space and is the first of the five elements of our letter "R".

As the first (rear) combination bar is in its left-hand position, it has rotated the connecting lever and the connecting lever has moved the selecting lever into the down position, allowing the operating lever to ride into its cam (all selecting levers being locked into place by the locking frame, which operates during the operation of the send/receive switch operation), allowing a space element to be sent. The next element to be sent is a mark; the second combination bar is in the right-hand side position; thus moving the left-hand side of the selecting lever to its higher position, thus stopping the operating lever dropping into its cam. Thus, the striker positioning lever is moved to the left, moving the striker to the right-hand side of the tongue over to the mark contact. The next element (third) is a space, the combination bar is in its left-hand position and the selecting lever will be in the down position, the third element striker positioning lever is allowed to drop into its cam, thus moving the tongue over to the left-hand side. The striker lever falls off its cam once more, the striker hitting the left-hand side of the tongue, moving it over to the space contact, giving our third element.

The fourth element is a mark and is sent in the same way as our first element and the fifth in the same way as the first and third.

During the third and fourth elements the transmitter detent is re-set; this is done in the following manner. The locking frame cam has completed half a revolution and hits against the tail of the detent release latch making it pivot clockwise, thus disengaging from the detent operating lever, letting the detent release latch cam follower rotate anti-clockwise, together with the detent control shaft and detent. The detent falls into the path of the clutch ratchet and is ready to stop the transmitter.

Before the cam can be stopped the 30ms stop signal element must be sent. When all the five code elements have been sent, the start/stop selecting lever is riding on the periphery of its cam, and thus the striker positioning lever moves to the right, taking with it the striker, which also moves to the right (space side of the tongue), the striker again falls off the node on the striker-timing cam, sending the tongue over to the mark contact sending out the 30ms stop element.

The node on the clutch ratchet hits against the detent projection, disengaging the clutch ratchet, from the gear

wheel with ratchet, the retention lever falls into its cam resetting the send/receive switch to the receive side and the transmitter is now ready for the next code to be sent.

The Creed Model 54 teleprinter with perforator attachment (Illustration by courtesy ITT-Creed Ltd).

THE 'OVERLAP' CAM UNIT

This unit is used in Creed Models 54 and 7E. Three sequentially operated cams cause the printing of a character immediately following the reception of the code for the character, instead of being printed one behind the received character.

An orientation device with pilot cam is fitted, but the main receive camshaft is split into two sections, and a friction clutch driven cam-line is added, driven through auxiliary gearing at the same speed. The sequence is that the pilot cam operates the friction drive "selector" cam, which near the end of the selection, releases the "translator" cam. This, after setting the code into the combination head, releases the "function" cam to print and to feed the carriage. While the translator and function cams are finishing their actions, the selector mechanism is restored, and a further character can be received. Although each cam section revolves in 130ms, the total time from the beginning of reception of any character to the end of the action initiated is 280ms.

Reception of the start space signal pivots the rockshaft clockwise, releasing the pilot clutch, which subsequently releases the friction clutch on the selector cam.

Mounted on the selector cam sleeve are five code cams, which operate five associated code levers, sequentially at 20ms intervals. Each code lever carries the lower end of the sequential lever, the upper end of which is pivoted in a finger push rod. When a code lever is moved clockwise, it takes the lower end of the sequential lever with it.

The rockshaft carries a compliant rocker blade. When a spacing signal operates the magnet, the magnet link pivots the rocker blade upwards, deposits the hollow in the sequential lever, which is not obstructed in its movements, and pivots in the push-rod, without imparting any motion to the latter.

On receipt of a marking signal, the rocker blade is moved downwards to a horizontal position opposite the step on the sequential lever. When a code lever moves outwards, the sequential lever comes into contact with the edge of the rocker blade, which acts as a pivot for that lever. The top end moves to the left, taking the pushrod and associated finger with it.

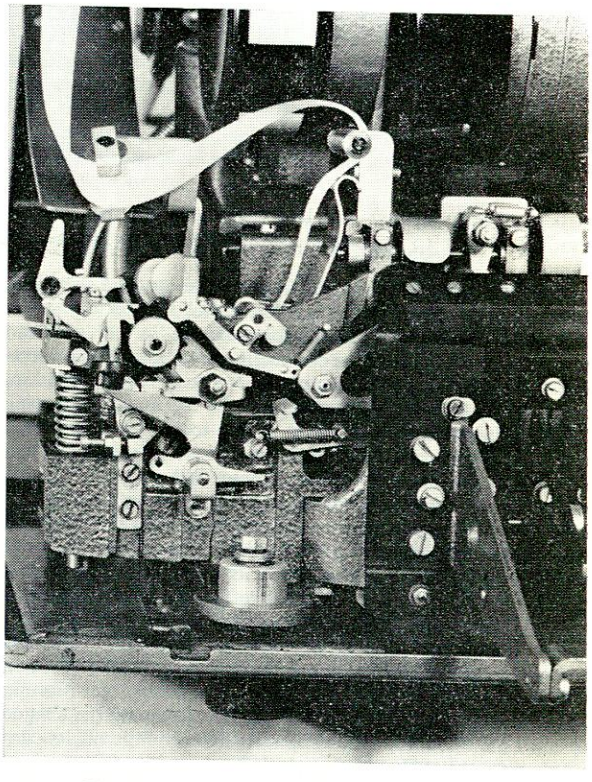
A series of code signals, operating the magnet, result in comb setting fingers being set under the comb ring extensions for a "mark" but not for a "space".

As possible signal distortion could change the position of the rockshaft during the read-off of a code element, giving a partially finished condition of the pushrod movement, a "chopper" cam is added behind the selector cam.

The chopper cam controls the action of the knife edged chopper. Immediately before the start of each read-off period, the cam profile allows the chopper to move in sharply against the rocker blade knife edge. This action assists the magnet action and firmly locks the rocker blade in the condition determined by the magnet, until the read-off of the signal element is finished, when the chopper lock is removed.

As the rocker blade is compliantly mounted on the rockshaft, the magnet can move the rockshaft in accordance with the next element, the rocker blade following sharply when the chopper lock is removed.

At the end of the read-off of the third element, a trip cam, mounted behind the selector detent, operates a trip linkage. This pivots clockwise, and moves the detent holding out the



The Creed Model 54 teleprinter, perforator unit.

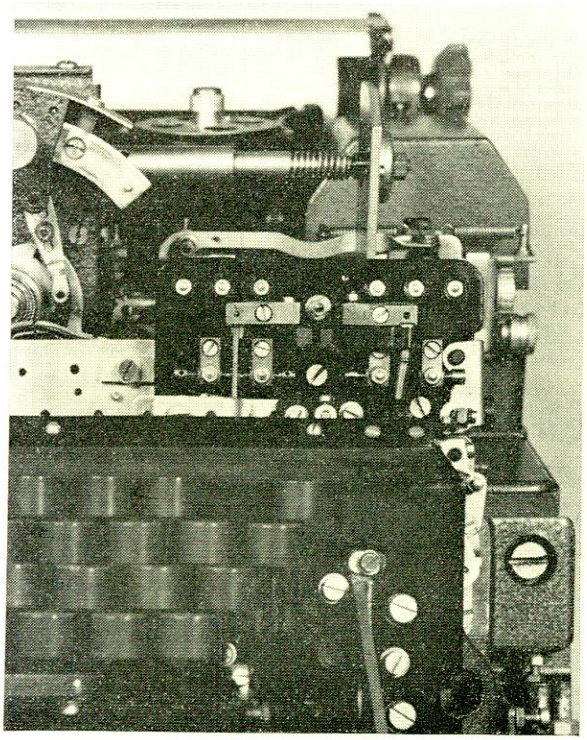
ratchet clutch pawls on the translator cam sleeve. As soon as the pawls engage fully in the ratchet teeth, the translator cam sleeve rotates anti-clockwise.

The translator cam sleeve carries two tracks, one controlling the bellcrank lift, and the other the action of the finger lift lever and its associated ribbon feed pawl.

Immediately the fifth code element read-off has been completed, the bellcrank lift collar is pushed in against the tails of the spring-load combination bellcranks. These are raised, releasing the pressure on the comb rings, which restore clockwise under their springs, and the typehead is released. The finger lift lever is then operated, and marking fingers, rising under the comb ring extensions, move the latter anti-clockwise. The ribbon feed pawl, attached to the finger lift lever, moves to engage the next tooth on its drive, ready to feed the ribbon as the lever restores, after setting the code on the comb rings.

Around the periphery of each comb ring, slots are cut in such a way that, for every combination into which the rings can be moved, an unobstructed slot is opened by all five comb rings beneath a pair of bellcranks.

Immediately after the bellcranks have dropped in, a node on the retention cam, just behind the pawl assembly, depresses the retention lever against its spring. This lever pivots anti-clockwise the trip linkage associated with the function cam sleeve trip detent: this is removed from under the clutch pawls which engage with their associated ratchet toothed gears.



The Creed 54 teleprinter, transmitter unit.

The function cam sleeves now commences to rotate anti-clockwise. It carries two tracks, one for the traverse lever and one for the type hammer. The traverse lever initially moves towards the front of the machine, during which movement it resets the marked fingers from under the comb ring extensions. This is done via a spring loaded pivoted lever, mounting on the rear of the traverse lever, which operates on to the pivoted finger reset linkage. An adjustable stop throws the two out of engagement, just as the fingers are reset.

TELEPRINTER 54: ADJUSTMENT SUMMARY

Adjustment	Tension or clearance	Remarks
Transmitter		
Striker timing lever	10–20mil	Striker in highest position. Striker held against upper edge of guide
Striker stop plate	15mil	Set up "All Marking", rotate until third and fourth selecting levers are resting on the contact operating lever. 15mil gauge inserted between third and fourth selecting lever and contact operating lever. Stop plate moved to the right and clamped
Transmitter contact gap	6mil	Striker must chop evenly on either side of tongue
Jockey roller pressure	4–5cz	
Tongue neutrality	4–5cz	Neutral
Send-receive switch		
Lever and buffer	4–6mil	Motor running
Contact gap	6mil	
Pawl abutment lift	3–20mil	Check on several keys
Resetting lever	6–20mil	Motor running
Key bar pressures	6–8½mil	Motor running. Not more than 1½oz difference between all keys
Trip bar back stop	5–6mil	
Locking bar No. 2	48–52mil	Free in guide plates
Comb bars	3½–4½oz	
Locking bar No. 1	4–5oz	
Trip bar overthrow stop	5–15mil	Key depressed
Receiver		
EM neutrality	Neutral	Checked with EM link disconnected
EM armature travel	9–11oz	
	28–32mil	
Comb setting and printing cam sleeves	Minimum end play	
Comb setting and printing cam sleeve pawl abutments	3–4oz	Pressure required to press released pawls back against cam sleeve seating
Comb setting cam sleeve retention lever	2–4mil	Retention lever fully embedded in cam
Comb setting cam pawl abutment trip	18–22mil	Trip lever fully raised by selector cam
Comb setting cam pawl abutment	11–15mil	Cam at rest. Release pawls. Press pawl abutment against side of pawls
Printing cam retention lever	2–4mil	
Printing cam pawl abutment bellcrank	20–23mil	Cam at rest. Release pawls. Press pawl abutment against side of pawls
Printing cam release lever	31–35mil	Machine at rest. After readjustments recheck pawl abutment bellcrank
Selector cam release lever		Motor running. Move orientation device clear and check with "Gauge, Pin, Double-ended"

Adjustment summary continued overleaf

CREED TELEPRINTER 54: ADJUSTMENT SUMMARY (concluded)

Adjustment	Tension or clearance	Remarks
Comb setting finger springs	1–2oz	Pressure to move each finger forward
Finger pressure springs	8–9oz	Measure on flat surface
Rockshaft	Minimum end play	Recheck EM neutrality. If heavier slacken rockshaft
Pilot cam clutch tongue	4½–5oz	
Pilot cam detent	13–17mil	EM to "space". Take up play on detent towards pilot cam lug
Selector cam clutch tongue	20–22oz	Release detent. Hook gauge on lug. Switch on motor
Bellcrank lift	2 mil min	Use "N" bellcrank
Comb setting finger lift	6 and 12mil	Use "N" bellcrank. After adjustment check ribbon feed
Ribbon feed	One tooth pitch	Make certain latch is released
Resetting of comb setting fingers	12–18mil	Clearance measured between comb extensions and fingers after resetting. *To readjust* Slacken and push "Push Bar Keep Place clear". With the resetting link held against the stop pin and *with the printing cam retention lever fully embedded* check 10–15mil gap between the resetting bellcrank and resetting link lever. Set up "All Marking", turning motor by hand until fingers are reset
	12–18mil	Check 12–18mil gap. Retain gap and position push bar keep plate to give 3–8mil clearance between push bars and keep plate.
Rocker blade vertical		Machine at rest EM to mark top of rocker blade level with steps in selecting levers
Rocker blade horizontal	3–20mil	Fingers set to "Mark" clearance measured between back of fingers and the receiving comb stop plate or finger resetting link whichever has the smaller gap. When readjusting make certain the blade is positioned so that all fingers are pushed in equal distance.
EM link eccentric	13–17mil	Motor running. If adjustment is unobtainable recheck "Rocker Blade vertical ADJ". Recheck pilot cam detent 13–17 mil
Traversing link damping	2–2½lb	Gauge applied at free end of damping spring
Spring tensions	Functional	
Control levers	Central	Bellcrank control on shoe
Control levers	18–44mil	Between front body plate and control lever tips
Typehead unit		
Type	7–8oz	
Typehead latch	Not more than 8mil side play	Pressure required to move types $\frac{1}{8}$in. Measure by taking up play in one direction, measure gap, take up play in other direction, measure the gap. The difference between the two measurements do not exceed 8mil
Latch spring	1¼–3¼oz	Pressure to just move latch

Adjustment	Tension or clearance	Remarks
Depth of engagement	55–66mil	Typehead play taken up towards clutch drum. Adjust with 5mil shims
Typehead end play	1–5mil	Adjust with 5mil shims. Not more than seven shims should be fitted
Clutch torque	10–12oz	If incorrect ascertain that the clutch spring is correctly in place
Typehammer		
Typehammer typehead clearance	$\frac{1}{16}$in	Play in typehammer taken up towards typehead
Typehammer head alignment	Hammer central on type	
Typehammer shackle spring	1 turn	Shackle spring compressed and then unscrewed one turn
Typehammer overthrow stop	5–15mil	Adjust gap to be correct on lower part of hammer head
Ribbon jumper		
Ribbon steady plate	2mil	Steady plate should not be bent
Ribbon lift	$\frac{1}{32}$in	
Answer-back unit		
A/B unit D key trip link	6mil	Unit at rest; detent fully engaged with stop-pin
A/B unit ward clearance	10–20mil	Ward in line with combination bars
Fitting abutment		
A/B unit detent	5–10mil	WRU bellcrank operate; check clearance between detent and ward barrel spindle stop-pin
A/B unit trip cam	Functional	
A/B clutch torque	12–20oz	
A/B release	1½lb	
Release of wards-barrel	8–9 turns	
Off-normal contact	20–30mil	
Off-normal contacts operating lever	20–30mil approx	
Off-normal contacts cam	$\frac{53}{64}$–$\frac{57}{64}$in	A/B unit in rest position
Off-normal contacts timing	2–2½ revs 3½–9¼ revs	Contacts close
Carriage units		
Chariot rail	Functional	
Carriage friction		
Carriage-return spring	2½–3¼lb 1¼–2lb	Carriage to the left Carriage near to the right-hand side
Letter-feed and letter-feed retention pawls		
Carriage unit dash pot	Functional	
Carriage unit stop plate	5–8mil	Unit at extreme right-hand side
Carriage latch	$\frac{1}{8}$in	
Clutch crosshead	10–25mil	
Letter feed dog	6–10mil	Feed throw-out lever in rest position
Carriage-return and line-feed dogs	10–15mil	Dogs in their rest positions
Line-feed mechanism	Functional	
Line-feed pawl eccentric	0–10mil	
Line-feed pawl buffer	Functional	
Pressure rollers	3–4½lb	
Chariot	Functional	Buffer spring lightly in contact with the chariot rail
End-of-line bell	Functional	Crosshead operated 55 characters
Pawl throw-out lever	1–5mil	Carriage mid-position and crosshead held to the right
Motor		
Motor speed	Correct	
Motor governor contacts	20–25mil	Clamp contact arm against the contact-arm stop

MAINTENANCE

General

Teleprinters are well made machines which deserve careful treatment. Adjustments must be accurately carried out, and owners should be absolutely sure that an adjustment is really necessary before attempting to do it. All settings are quite logical and take into account the functions of the parts concerned. Too little pressure or tension will result in erratic operation and too much pressure or tension will increase wear and shorten life of the parts. Failure of a part to move correctly is more likely to be due to frictional obstruction, arising from dirt or lack of lubrication, than lack of spring tension.

A good idea, before operating the machine, is to turn the motor over slowly by hand, observing at the same time the functions of the various levers and noting any tight spots. It may be possible to locate binding parts or loose parts by doing this simple operation.

Besides observing the machine functions when first inspecting a machine, it should also be checked for corrosion mildew, overheating, tension, wear, poor electrical contacts, frayed electrical wiring and general condition.

Cleaning a machine should be carried out carefully and leisurely. Foreign matter can be removed by a brush, such as a one inch paint brush or with a clean non-fluffy cloth. Type faces may be cleaned with a typewriter brush or with a tooth brush, taking care not to bend the type bars.

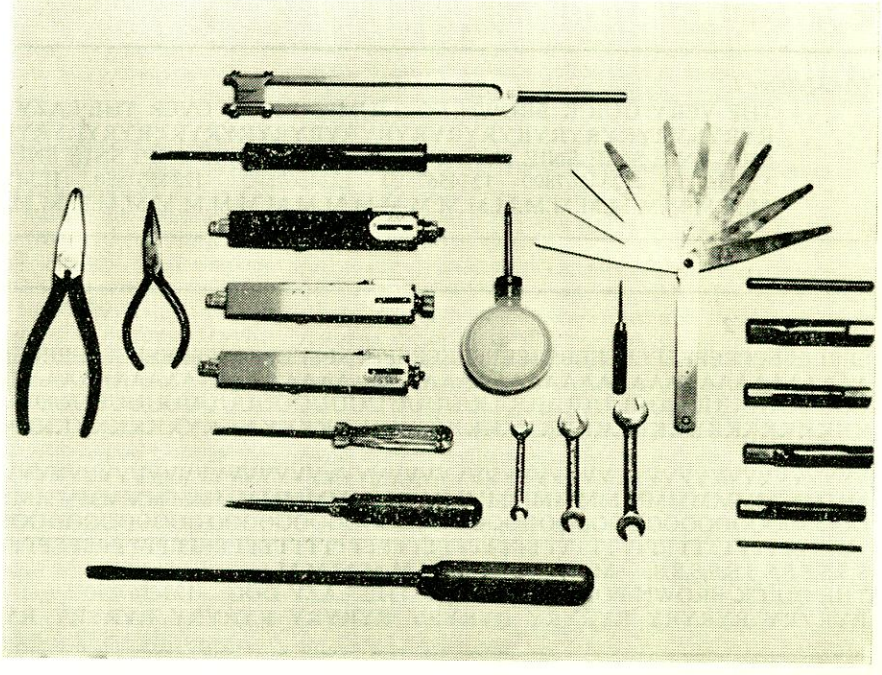
Lubrication

Before oiling, dirt and surplus oil should be cleaned away. This should be done with a non-fluffy rag or with paper towels. Old and gummy lubricant, dust and fluff are the worst enemies of light mechanisms and owners are advised to cover their machines when not in use, and to keep them in warm dry rooms at all times. Pure carbon tetrachloride applied with a good quality camel hair brush will wash away old lubricant, and will itself evaporate quickly, but this operation should be carried out in a well ventilated room. Other common solvents, suitable for cleaning teleprinters of old oil, etc are methylated spirit, white spirit, and petrol.

Some parts of teleprinters must be kept completely from any lubricant and such parts may be treated with an oil repellent. An oil repellent may be made up of 5 per cent stearic acid and 95 per cent toluene. It should be noted that this mixture is inflammable. The parts to be treated should first be cleaned in pure petrol to remove any dirt, etc, after which they are placed in the solution which has been heated to a temperature or 30°–40°C in a water bath. The parts are then removed one item at a time and immediately dried thoroughly with a clean woollen cloth. Do not allow air to dry them. This colourless oil repellent applied forms a very thin film which adheres well to clean metal surfaces.

When oiling, care must be exercised to avoid over lubrication, and any excess oil must be wiped off before operating the machine, otherwise it will be thrown over the mechanism and will collect dirt.

The easiest way to obviate over-lubricating a machine is never try to squirt oil from an oil can, however small it may be. A better method of applying oil to a particular point where only one or two drops are required is to use a short piece of wire. The wire is dipped about $\frac{1}{2}$in into the oil and then applied to the point immediately. Other methods are to use an oil pen or a hypodermic syringe. A hypodermic syringe is also very useful when applying oil to a felt which has to be saturated. When saturating these felts, it is usual practice to soak them in a shallow pan of oil, but using a



Essential Tools

Screwdrivers, large, medium and small
Feeler gauges
Spring gauges
Strobe fork
Oil can
Spanners, open ended and box
Pliers, large and small

(see also p 2.131)

hypodermic it is possible to oil them from the "inside out" even when they are still on the machine.

Tools

A basic tool kit is essential if any adjustments are to be carried out on a machine. The captions list the tools considered essential and those considered very useful. Not listed are any special tools required for specific jobs on individual machines. Such tools are usually obtainable from the machine manufacturers.

Test Messages

Certain adjustments on the teleprinter, notably those on a page printer, although correctly adjusted to specified figures with the machine stationary may not give optimum running performance, and may need readjusting after or during a period of running.

To enable a machine to be fully tested, and any obscure faults highlighted the following test messages, are suggested. These messages should be prepared on punched tape and fed into an auto transmitter of known performance.

Explanatory Notes: Test message 1

1st line: checks alphabet, also carriage return (the first "THE" has carriage return sigs. after each letter, with spaces, so that "THE" will be correctly printed).
2nd line: tests selection.
3rd line: tests typehead clutch of Creed Types 3 and 7.
4th line: checks figures.
5th line: tests case change.
NOTE: all end-of-line dots should line up vertically, as a quick check on feeding, missing etc.

Explanatory Notes: Test message 2

Line 1 checks code element No. 1 (MSSSS)
Line 2 checks code element Nos. 1 and 2 (MMSSS)
Line 3 checks code element Nos. 1, 2 and 3 (MMMSS)
Line 4 checks code element Nos. 1, 2, 3 and 4 (MMMMS)
Line 5 checks all five code elements (MMMMM)
Line 6 checks code element Nos. 2, 3, 4 and 5 (SMMMM)
Line 7 checks code element Nos. 3, 4 and 5 (SSMMM)
Line 8 checks code element Nos. 4 and 5 (SSSMM)
Line 9 checks code element No. 5 (SSSSM)
Line 10 checks the figures/letters case shift mechanism
Line 11 checks every individual letter and figure
Line 12 checks the operating limits of the mechanism by alternating "Rs" (SMSMS) and "Y"s (MSMSM)

Ribbons

For best performance, proper teleprinter ribbons should be used as they are stronger than ordinary typewriter ribbons and stand up better to the much heavier use. If, however, typewriter ribbons only are available, a careful watch must be kept for fraying, as a ribbon thread if drawn into the mechanism can cause much damage, if for example it wraps itself around rotating shafts and tangles with reciprocating levers.

If a machine has been left standing for a while, the ribbon ink can dry out. There are available ribbon re-inking kits, but a satisfactory method of rejuvenating dry but otherwise sound ribbons is to soak them in a shallow pan of stamp-pad ink, or even thin lubricating oil. The ribbon is left wound on its spool and is placed in the pan, which should have ink to a depth of about $\frac{1}{16}$in and allowed to soak for an hour. The ribbon is then removed and allowed to drain off any surplus ink for about 24 hours, after which it may be replaced on the machine. The pan should be only slightly larger in diameter than the wound ribbon.

Test Message 1

THE VERY QUICK BROWN FOX JUMPS RIGHT OVER THE LAZY OLD DOGS BACK.
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRY.
SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE SNIE.
1234567890 1234567890 1234567890 1234567890 1234567890 1234567890 1234567890.
M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M..

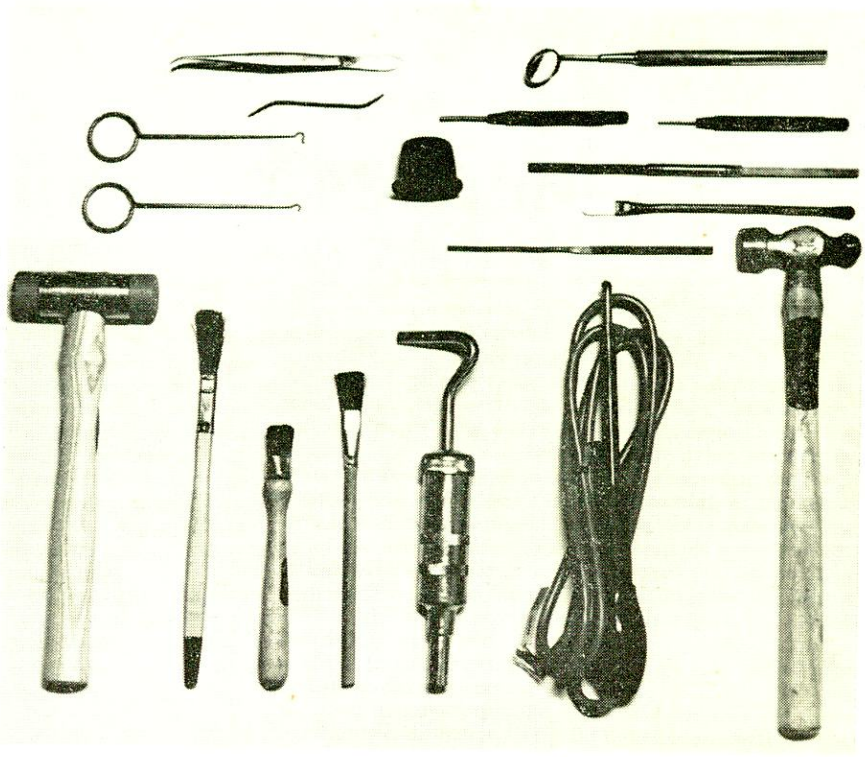
Test Message 2

EEEE

Useful Tools

Brushes, paint and typehead
Contact burnisher
Inspection mirror
Spring hooks
Eye glass
Tweezers
Parallel punch
Tommy pins
Small engineer's hammer
Soft face hammer
Soldering iron, 25W
Cleaning rags (not shown)
Swiss file
Grease gun
Container for washing out ballraces, etc (not shown)

(Compare with "Essential Tools", p 2.129)



ORIENTATION DEVICES

When an orientation device or rangefinder is fitted, the reception of a start signal releases a pilot cam which in turn controls the delayed release of the receiving cam sleeve. On Creed machines operating at 50 bauds, the extent of the delay introduced may be adjusted from 11·7 to 31·7ms. The receiving cam sleeve on a Creed machine, fitted with an orientation device, is similar to that of an ordinary machine except that the cam is advanced by 60 degrees (21·7ms) in its rest position. Thus the timing operation performed by the cam after receiving the start signal may be varied from $-21{\cdot}7 + 11{\cdot}7 = -10$ms to $-21{\cdot}7 + 31{\cdot}7 = +10$ms, in relationship to the corresponding timing operation of a receiving cam without orientation.

Therefore, by adjustment of the relationship between the pilot cam and levers which control the release of the receiving cam sleeve, the instants of selection of the code elements may be varied by plus and minus 10ms, that is 50 per cent of a code element. This allows the selection mechanism to be correctly phased so that selection is effected during a short period in the middle of each code element.

It should be noted that on a Creed machine with orientation, at rest, the finger setting pin is in line with the first selecting finger instead of opposite the third selecting finger on a machine not so fitted.

Adjustment of Orientation Device or Rangefinder

For adjustment, the teleprinter should be fed with a tape derived test signal. The standard one, The Quick Brown Fox Jumped Over The Lazy Dog 1 2 3 4 5 6 7 8 9 0 followed by a line of RYs is ideal. (The sentence contains every letter of the alphabet, and RY's are code reversals). The teleprinter is turned on and the test message is fed to it. While copying the test tape, the orientation device should be slowly set down to the lowest value until the machine prints errors. This value should be around 10 for a properly adjusted machine, and the exact setting should be noted. The orientation device is then set to the upper end of the scale and the point at which errors occur is again noted. The value should be around 90.

The difference between the readings quoted above is 80, and this is known as an 80 point range or margin. The correct setting for the orientation device is $10 + 90$ divided by $2 = 50$. Any errors will be at a minimum at this setting.

If range values of approximately 10 and 90 are unobtainable, the appropriate adjustments to the teleprinter should be re-checked and the range adjustment procedure carried out again.

CHAPTER 3

OTHER RTTY MACHINES

Teleprinter Automatic Transmitters

INTRODUCTION

THE teleprinter automatic transmitter is a telegraph machine designed to transmit five-unit code signals in accordance with perforations in a paper tape which has been previously prepared by a perforator or reperforator. Such a machine consists basically of a motor driving a transmitting head which is under the control of a tape-control unit. The transmitting head contains a paper feed mechanism, and the mechanism which controls the generation of the start and stop signal, and the sensing arrangements which convert the conditions on the tape to electrical signals.

For amateur radio use, there are two generally available types of machine, those made by Creed and those by Teletype. Both types of machine work in the manner described but, as there are definite differences between them in the method of approach, the two types will be described separately.

OPERATION OF AN ELEMENTARY MACHINE (CREED)

Tape-control Unit

To maintain a constant speed of sending, the driving motor must not be coupled to the transmitting head before it has reached its governed speed. The ratchet and pawl type clutch is controlled by the tape-control unit, and before starting the motor the tape-control lever is manually placed in the upper position, thus disengaging the clutch pawls from the driving spindle ratchet. See **Fig 3.1.**

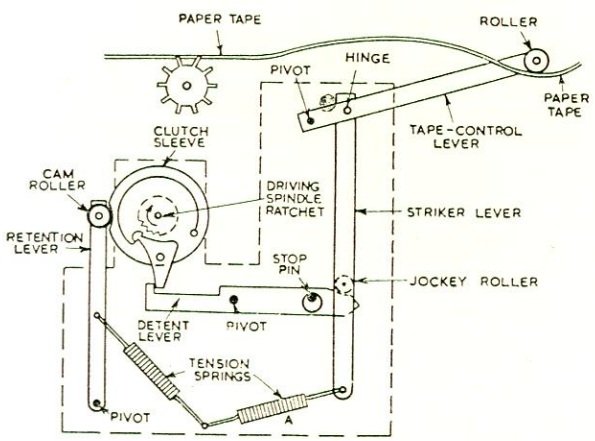


Fig 3.1. Diagram of tape control unit as used on Creed 6S series automatic transmitters.

The message tape to be transmitted is passed under the roller on the tape-control lever and its feed holes engaged with the paper feed wheel in the transmitting head. The motor is then switched on, and when it has reached its governed speed the tape-control lever is moved to the lower position. The striker lever moves down and, as the detent lever is held by the stop pin, the jockey roller rides over the tip of the detent lever and bears against its lower inclined surface. The detent lever turns anti-clockwise on its pivot to the limit set by the stop pin, and the movement is sufficient to clear the pawls and allow them to engage the driving spindle ratchet.

With the clutch engaged the clutch sleeve rotates at the normal working speed and

(*a*) a cam-shaft and the paper feed wheel in the transmitting head rotate with it, and signals appropriate to one character are transmitted for each revolution of the sleeve.

(*b*) a send receive switch, if fitted, moves to the send contact immediately and returns momentarily to the receive contact at the end of each revolution.

If the flow of tape to the transmitting head is arrested, the transmitter signals are likely to be distorted and the tape mutilated by the feed wheel. If the stoppage occurs at a point before the roller on the tape-control lever, the loop of tape in which the roller rests shortens and lifts the control lever. The jockey roller on the striker lever rides up on to the middle inclined surface of the detent lever, causing the lever to arrest the clutch pawls and so stopping the drive to the transmitting head.

The Transmitting Head

The perforated tape is drawn over the upper ends of five vertical rods or peckers, which are located to correspond with the five code elements of a character on the tape. Each pecker is associated with a cam and tension spring and is linked through a common operating lever to a contact tongue. See **Fig 3.2.** The cams associated with the peckers are positioned radially so that in one complete revolution of the cam shaft all the peckers rise and restore in turn. The tape feed wheel is geared to the cam shaft so that the tape is advanced by one feed hole for each revolution of the cam shaft.

During the time that a character is above the peckers the cam shaft moves through one revolution and, commencing with the first signal element, each element in turn is sensed by its associated pecker. In an elementary transmitter the holes in the pecker guide plate will require to be elongated and

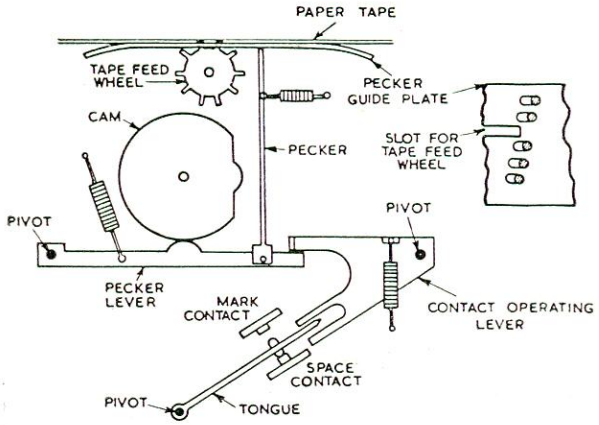


Fig 3.2. Creed 6S1 transmitting head.

staggered to allow for the forward movement of the tape while the elements are sensed. Those peckers associated with mark signal elements, ie perforated elements, are allowed to rise to their fullest extent but those associated with space elements are restrained by the paper. A pecker which is allowed to rise turns the contact-operating lever on its pivot and so moves the contact tongue to the mark side. If the next pecker is restored by its cam, the contact-operating lever and the contact tongue are therefore held in the mark condition. When the next pecker is associated with a space element, the pecker is in the normal position and consequently the contact-operating lever restores to normal and moves the contact tongue to the space side.

The start and stop signals which are associated with the five-unit code for each character are generated by means of a cam, which is mounted on the same shaft as the signal element cams, and a start-stop lever which is similar to and mounted on the same pivot as the pecker levers. The positions of the cut-aways in the cams relative to each other and with the start stop cam at the normal position are shown in **Fig 3.3**. In practice, to keep the length of the cam shaft to a minimum, the start-stop cam is positioned in the space occupied by the feed holes, that is between the second and third signal elements. The humps on the pecker and start-stop levers coincide with the vertical reference lines when the cam shaft is at the normal position.

At the normal position the start-stop lever is bedded in the recess of its cam, thus holding the contact lever and, therefore, the contact tongue, over to the mark side. When the cam shaft begins to rotate, the start-stop lever immediately rides out of the recess and allows the contact operating lever to turn under the tension of its spring and move the contact tongue to the space side. When the space or start condition has existed for a cam shaft angle corresponding to one code element, the recess in the cam associated with the first code element is fully engaged with its pecker lever and

(*a*) if the first element is a perforation the pecker lever will rise and cause the contact tongue to change over to the mark side, or

(*b*) if the tape is not perforated the pecker lever is held in its original position and the contact tongue remains on the space side.

The cam shaft continues to rotate and at angular intervals equivalent to code element periods the second to fifth code elements are determined in a similar fashion. At the end of the fifth code element the start-stop lever is engaged with its cam recess and

(*a*) if the fifth code element is a space signal the upward movement of the start-stop lever turns the contact operating lever and so causes the contact tongue to move to the mark side, or

(*b*) if the fifth code element is a mark signal, the upward movement of the start-stop lever maintains the contact operating lever and, therefore, the contact tongue, at the mark position.

The mark stop signal exists until the cam shaft completes the revolution, and this is equivalent to one and a half code elements. The cam shaft is continuously rotating while the tape-control lever is in the lower position and, therefore, the start signal for one character immediately follows the stop signal of the previous character.

The foregoing description applies to the older Creed machines, such as the 6S1, 6S3, etc shown in **Figs 3.4** and **3.5** and to be found in many stations.

Later versions of these machines, such as the 6S6, **Fig 3.6**, follow closely the laid-down principles, but have detailed refinements such as:

1. A striker type of transmitting mechanism, similar to that used on the Creed 7B teleprinter, **Figs 3.7** and **3.8**;
2. A tape feed mechanism which provides step-by-step feeding, so that the tape remains stationary whilst being sensed. On this, the peckers are in line and not staggered.

Some versions may be found which have electromagnetic clutches and others with a powered take-up spool, driven from ratchet motion derived from the cam shaft, **Figs. 3.9** and **3.10**. Others have an arrangement which stops the mechanism

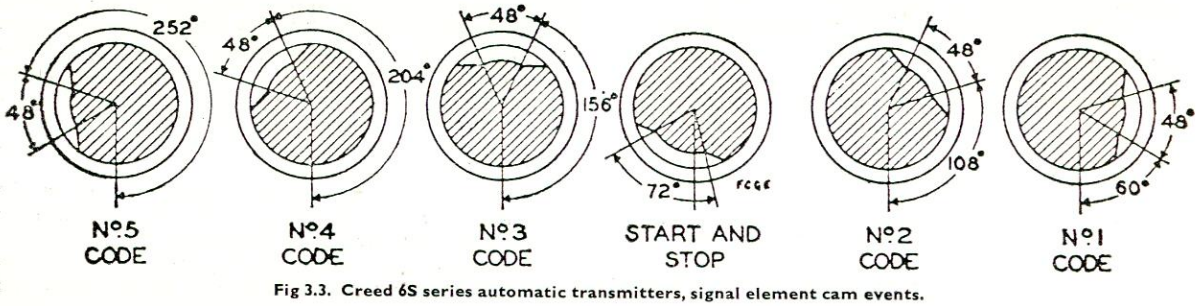


Fig 3.3. Creed 6S series automatic transmitters, signal element cam events.

when there is no tape in the head by disconnecting the drive via a magnetic clutch.

Description of Striker Transmitting Mechanism

The cam-sleeve in the transmitting head has a timing cam secured on its rear end, which has seven indentations cut in the periphery. The cam is secured to the cam sleeve so that the indentations are in the correct phase relationship with the corresponding flats on the pecker cams. In **Fig 3.7** the mechanism is shown in the condition where a pecker has risen through a perforation marking the fourth code element in the tape, and the striker timing lever is just about to enter

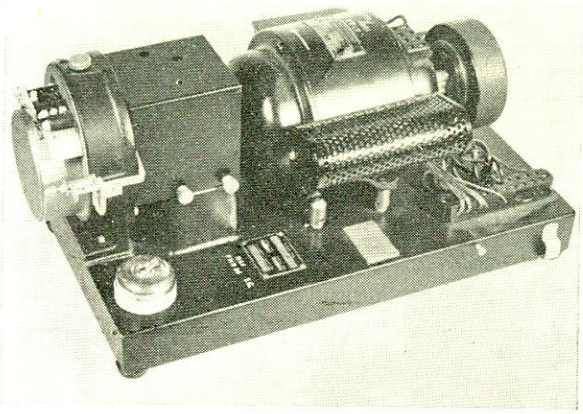


Fig 3.4. Creed 6S1 automatic transmitter.

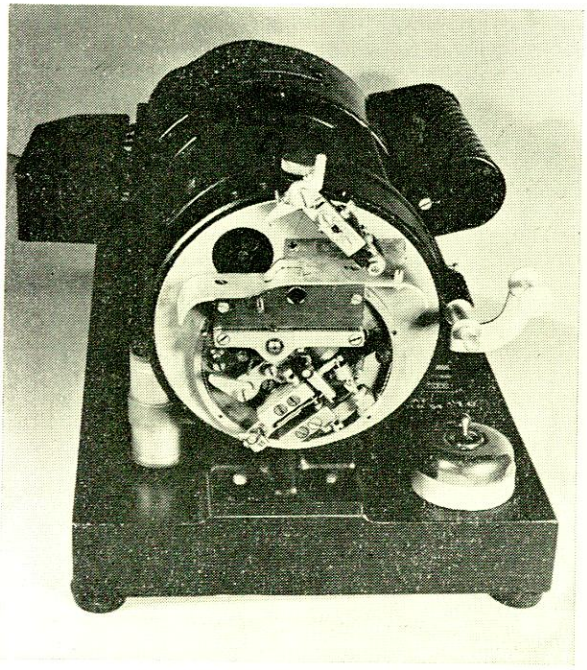


Fig 3.5. Creed 6S1 transmitter head.

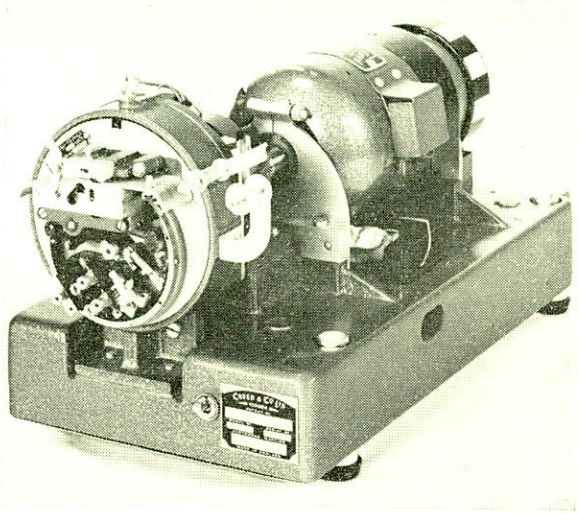


Fig 3.6. Creed 6S6 automatic transmitter.

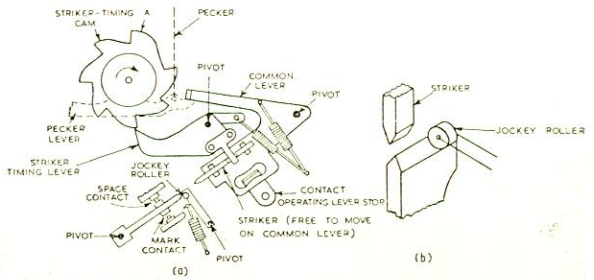


Fig 3.7. 6S6 transmitter head, diagrammatical layout.

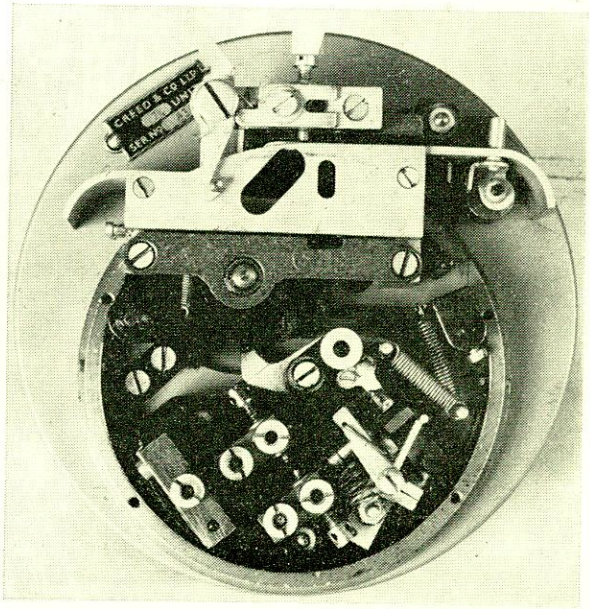


Fig 3.8. 6S6 transmitter head.

a notch in the striker-timing cam. The common lever has been turned on its pivot by the pecker, and when the timing lever enters the notch on the timing cam the striker will be pushed down to move the contact tongue over to the mark contact. If the next code element is a space the appropriate pecker will not rise, and so when the striker is forced down by the timing lever the contact tongue is moved back to the space contact. The longer tooth on the striker timing cam is necessary for the stop signal, and at the end of sending a character and its stop signal the point A on the striker-timing cam coincides with the striker-timing lever.

Motors

The Model 6S1 was fitted with a centrifugally controlled dc shunt field motor, rated at $\frac{1}{25}$hp (26·5W) and was available in four voltage ranges, 100–110V, 150–170V, 200–220V and 230–250V. Speed was 2,940rpm for 49 baud operation, or 3,000rpm for 50 baud operation.

Later machines, such as the 6S3 etc, may be found with motors for low voltage dc (shunt wound), ac or dc (series wound) for various voltages, or motors with two ac or two dc windings or one ac and one dc tapping. It should be noted that these later type of motors run at 1,500rpm.

Mechanical Details and Adjustments

Electrical connections between the head and the transmitter frame into which the head is fitted is effected by three pins, which are connected to the "marking" contact, the contact tongue and the spacing contact. These pins engage with phosphor bronze springs mounted on an insulating block fixed to the transmitter frame, and wires from the back of these springs are connected to the terminal strip on the main base. For ease of access the transmitter head may be removed from the main machine by unscrewing the knurled screw on top of the transmitter stand to its fullest extent and then withdrawing the head.

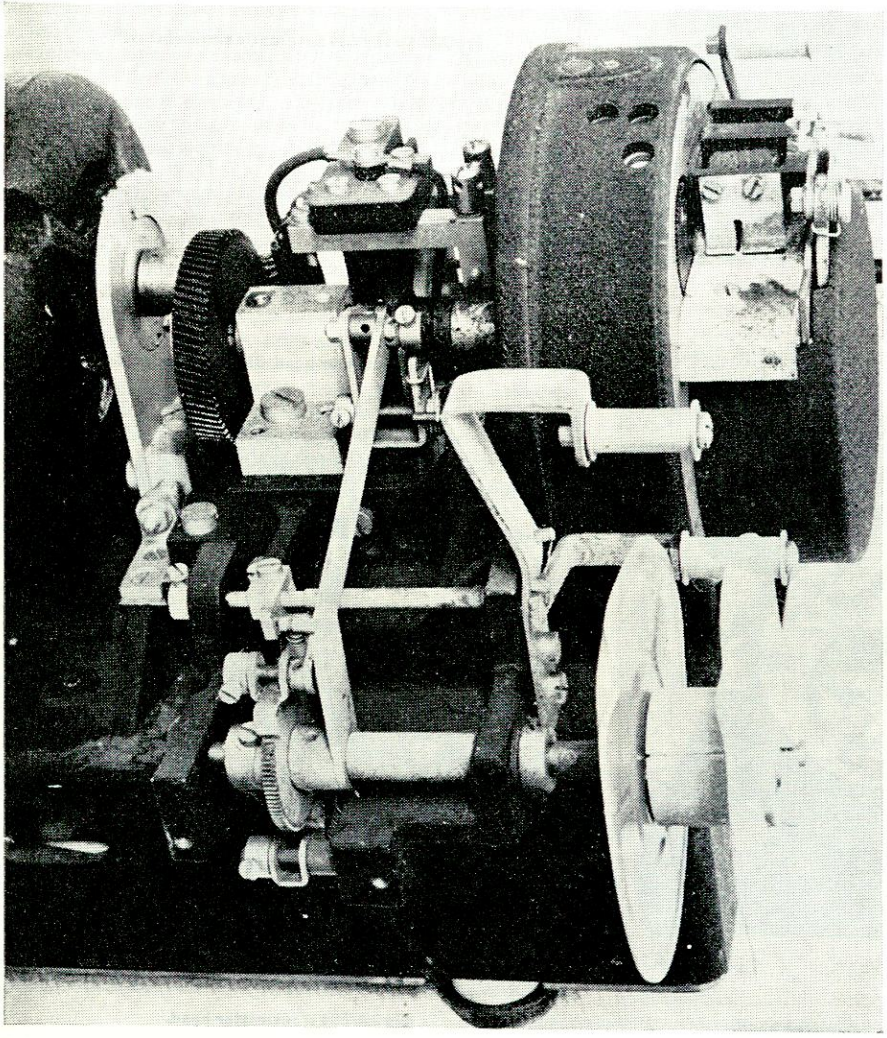


Fig 3.9. 6S series automatic transmitter, powered take-up spool.

When any one of the peckers is in the "up" position the pressure required on its tip to depress it flush with the guide plate should be between 160–185g.

If the mechanism is rotated until the third selector lever from the back has just gone back to its rest (or down) position, the pressure needed to raise the operating lever at its point of contact with the selectors should be 62–68g.

The contacts should not only be clean, but should be burnished to give the best results. They should on no account be cleaned with emery paper or other abrasive, as the particles become embedded in the surface of the platinum. This sets up excessive sparking and consequently bad signals are sent out. If the contacts are badly pitted, a very fine file, such as a watchmaker's superfine file, should be used, followed by a highly polished steel burnisher. A burnisher alone, used regularly, should be sufficient to keep the contacts of properly installed apparatus in good order.

After altering the position of the contacts they should be adjusted as follows:

Turn the mechanism by hand until two peckers are in the mid-way position. Close up and adjust both contact screws so that the tongue is positioned centrally. Open out each contact by 0·003in to give a final contact gap of 0·006in. Then adjust the jockey roller eccentric so that equal pressure is required to move the tongue to either side; ensure that both screws on lever are tight. The jockey roller pressure should be set as follows:

Apply a 0–200g preset balance to the end of the tongue and vertical to it, just below the jockey roller itself. Vary the pressure by means of the knurled nut, until a reading is obtained on the balance of between 90–100g. Lock the spring adjustment knurled nut by means of the hexagonal nut.

TELETYPE MODEL 14 TRANSMITTER- DISTRIBUTOR (14-TD)

Method of Operation

The perforated tape is fed into the tape head where the holes representing each character are sensed and made to apply mark or space voltages, as appropriate, to the various segments of a distributor. These voltages are keyed to the loop circuit sequentially by rotating brushes which traverse the segments and collector ring at the signalling speed.

The Tape Sensing Mechanism

There are five vertical tape hole sensing pins located under the reading head, positioned two on one side and three on

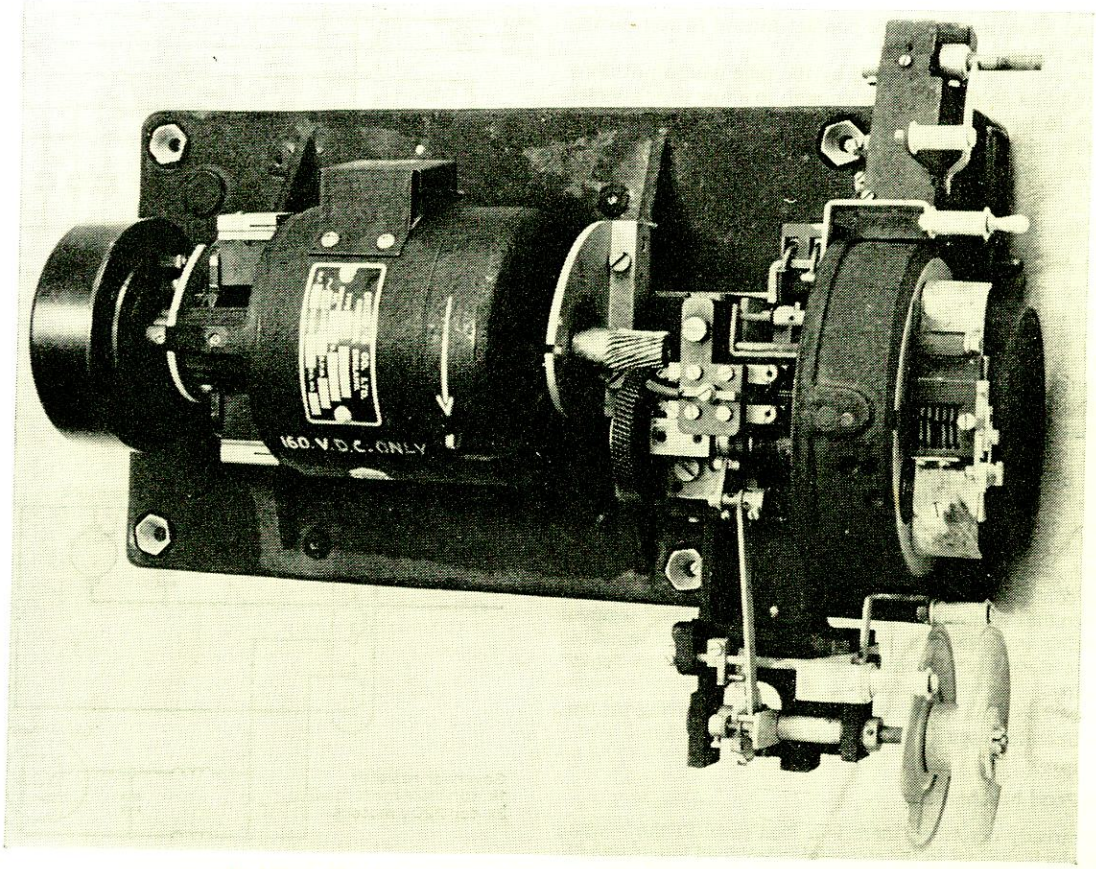


Fig 3.10. A 6S series automatic transmitter with powered take up spool.

the other of the driving pinion which itself engages the series of chad holes punched along the tape.

The sensing pins are free to move vertically and each in turn carries a contact tongue moving between fixed mark and space contacts. A contact lever spring is attached to the mounting end of each contact tongue and tends to hold it against the lower contact screw. This assembly is revealed by the removal of a "snap on" cover surrounding the reading head.

A contact lever bail pivotally mounted just below the contact lever lower extensions has an arm extending downwards to engage the transmitter operating lever. This lever has a central pivot and moves horizontally. The end of this lever carries a roller which bears on a cam mounted axially on the lower end of the distributor vertical drive shaft.

Rotation of this shaft moves the lever horizontally causing the contact tongues to move up and down between the marking and spacing contact screws.

The contact lever springs absorb any additional motion after the tongues have reached the top contact screws. The "stop" position of the distributor places the roller of the transmitter operating lever at the highest point of the cam described above. This has the effect of holding the tape sensing pins clear of the tape by downward withdrawal. As the cam rotates with the distributor the pins rise in contact with the tape. If the latter has any perforations in any of the five sensing pin travels, the pin concerned will pass through the hole and allow its associated contact tongue to rest on the marking contact.

Those pins that are stopped by the tape whose positions have no holes do not move far enough to allow their contact tongues to leave the spacing contacts. This state of affairs persists during the time taken for the distributor brush to travel over segments one to five.

The Distributor

This consists of two concentric copper conducting rings mounted in an insulating moulding. The outer ring is divided into seven segments. Segments one to five inclusive correspond to the five intelligence units of the five unit code and are wired to the five contact tongues in the tape sensing mechanism.

Immediately preceding segment 1 is the "start" segment and that following number 5 is the "stop" segment.

The "start" segment is wired to the upper contact screws which in double current applications is connected to the "space" polarity of the supply. The "stop" segment and lower contact screws are wired to the "marking" polarity of the supply.

In single current applictions the "start" segment and the upper contact screws have no supply connections.

When the distributor brush passes over the "start" segment a spacing impulse is always transmitted, and a marking impulse always results when the brush traverses the "stop" segment.

These two invariable impulses cause the receiving printer, etc to operate in synchronism with the brush arm.

Tape Feed Mechanism

As already described there is a feed pawl in the reading head which engages in the chad holes punched longitudinally down the tape.

The cam on the distributor drive shaft which moves the contact tongues also drives this pawl. The movement of the pawl takes place after the tape sensing pins have been withdrawn and the transmitter operating lever roller is traversing the "stop" segment and the pawl is impulsed on a click wheel so that the tape is advanced a distance sufficient to bring the next line of holes for the succeeding character to the reading position.

Starting and Stopping

The main shaft is driven by a motor via a gear train and a friction clutch. When the motor is running transmission is stopped by blocking the rotation of the main shaft and started by unblocking it. This is effected by a stop arm attached to a spring loaded solenoid. When energized this solenoid holds the stop arm clear of the lug and when de-energized the spring carries the stop arm to engage with the

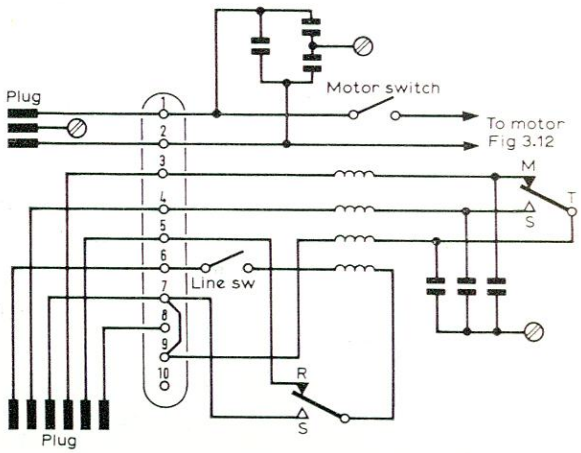


Fig 3.11. 6S1, signal wiring.

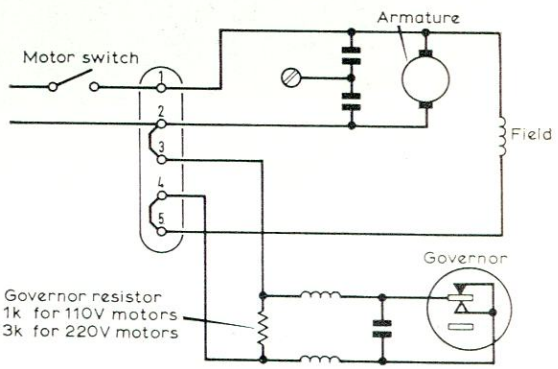
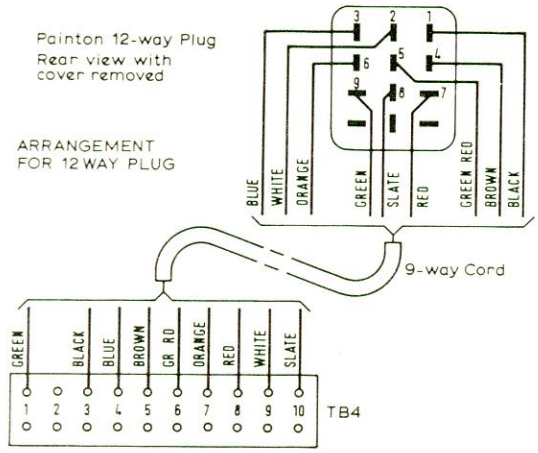


Fig 3.12. 6S1, motor wiring.



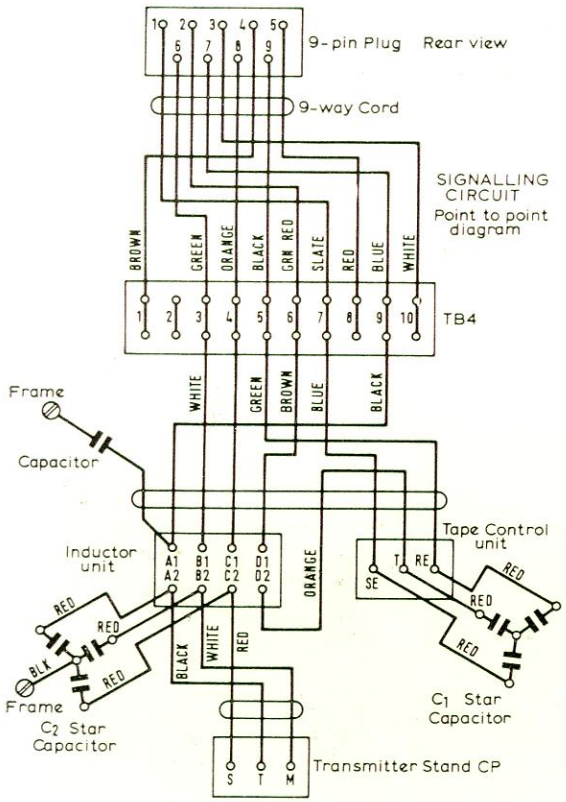


Fig 3.13. 6S3, signal wiring.

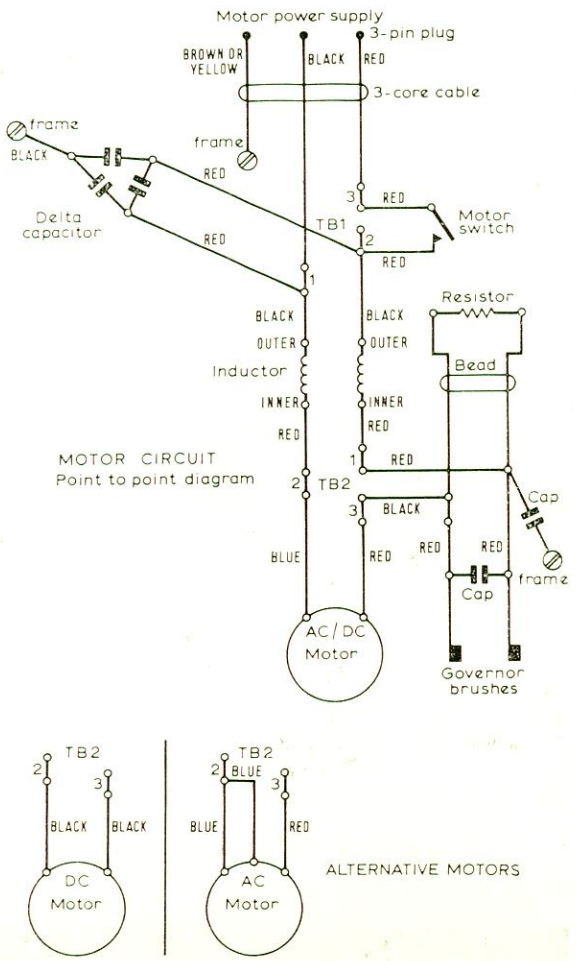


Fig 3.14. 6S3, motor wiring.

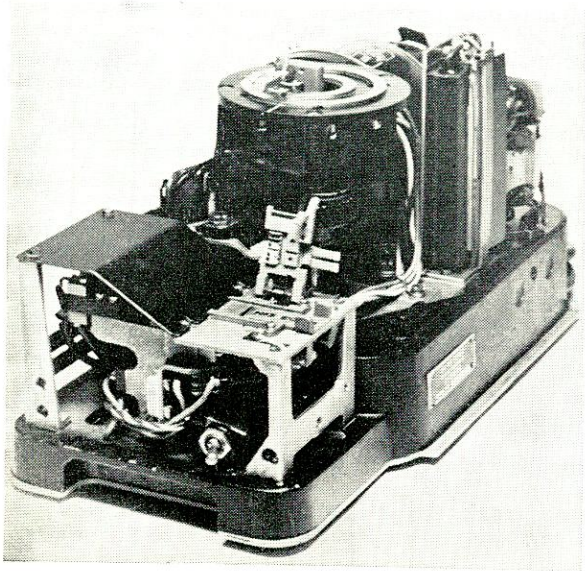
lug. This operation of the solenoid can be controlled by any of three devices.

(*a*) Tight tape mechanism.
(*b*) End of tape stop mechanism.
(*c*) Tape stop switch.

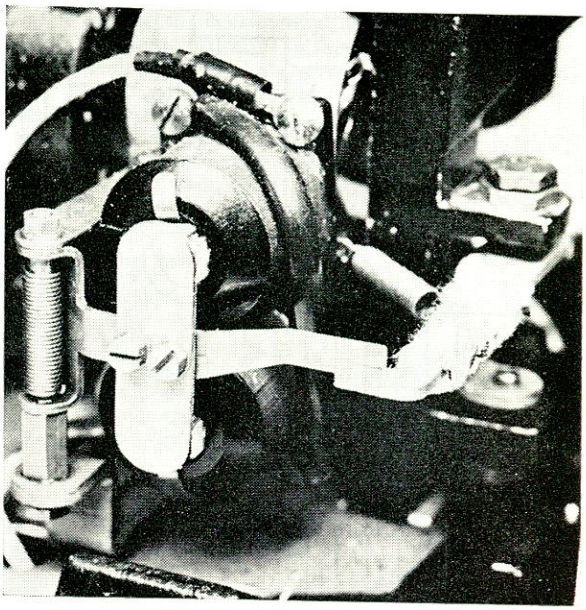
(*a*) *Tight tape stop.* This is an arm under which the tape passes before entering the reading head. When tape to be read becomes taut and may be liable to mutilation, the lever rises, operates the stop solenoid and halts transmission till the tape becomes slack again when transmission is automatically resumed. This allows tape being prepared in a perforator to be fed directly to the 14-TD without risk of tape damage. This mechanism may be missing from some 14-TD's which become available.

(*b*) *End of tape stop.* Beneath the tape guide to the reading head is a sensing finger projecting from below which is held down by the tape edge and is only allowed to rise under light spring pressure when the tape is exhausted. This finger

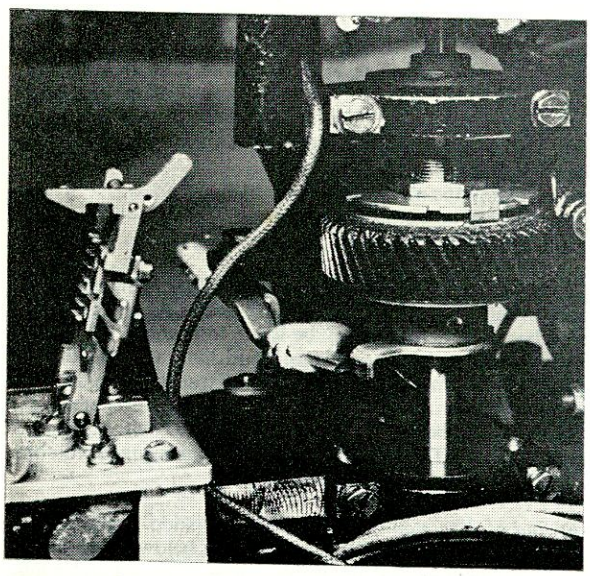
TELETYPE DETAIL



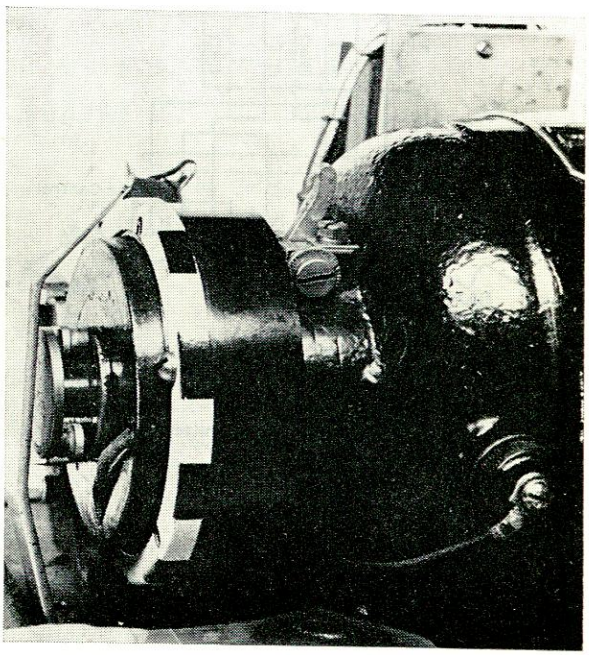
Detail of the Teletype Model 14TD.



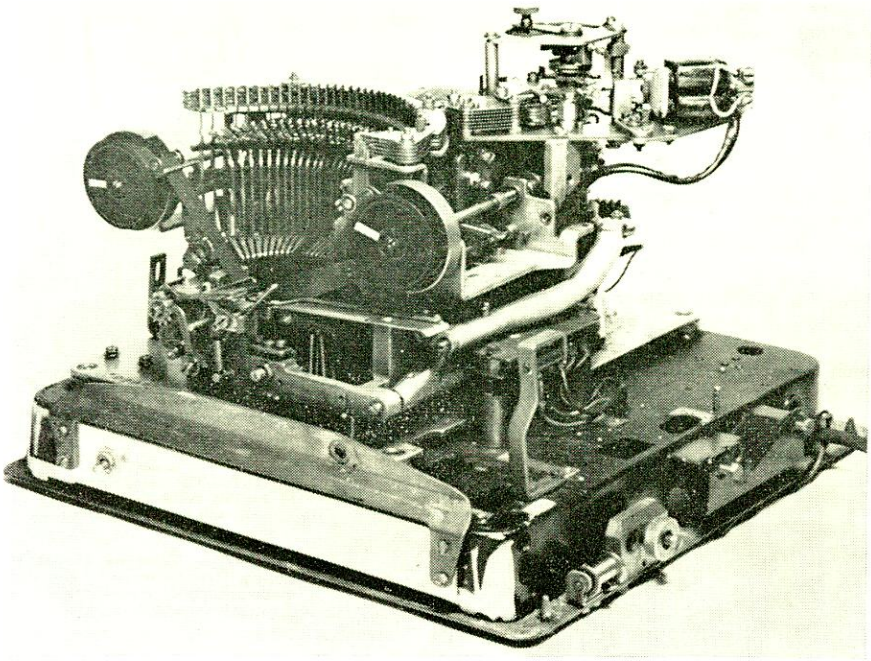
The 14TD clutch lever and clutch magnet.



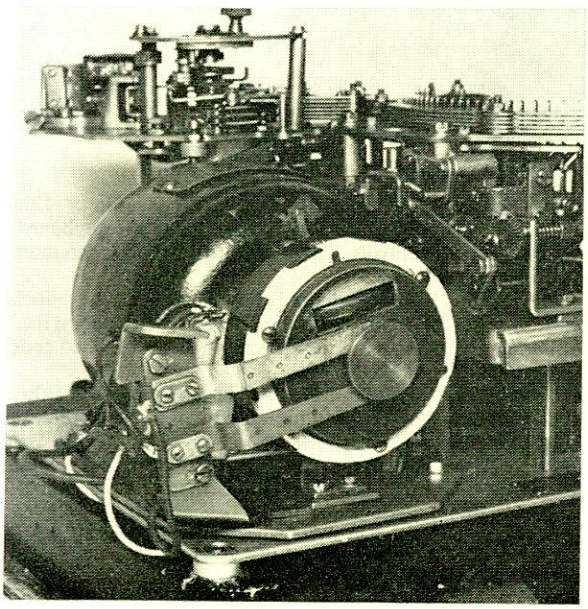
Teletype 14TD, showing clutch and drive pinion.



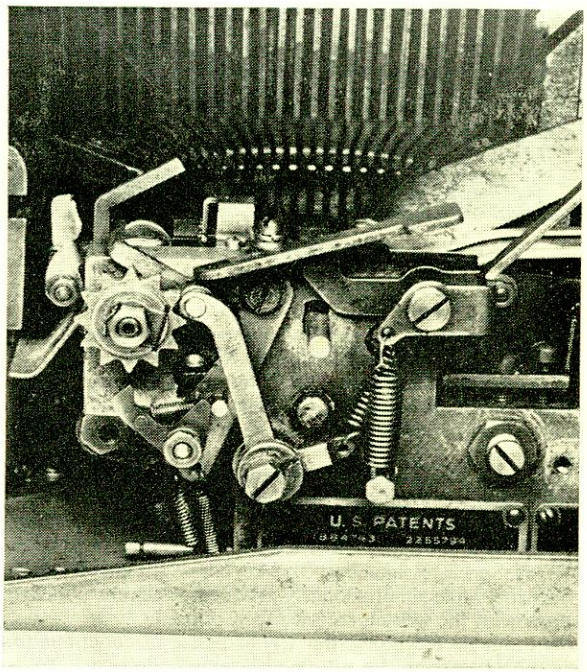
Typical Teletype governor as fitted to a 14TD.



Teletype Model 14 typing reperforator.



Teletype 14 typing reperforator, showing motor and governor.



Model 14 typing reperforator, showing typing head and tape feed lever.

operates contacts which in turn control the stop solenoid, thus once tape runs out of the reader transmission ceases.

(*c*) *Tape stop switch.* This is located on the front of the 14-TD below the reading head and controls the stop magnet manually.

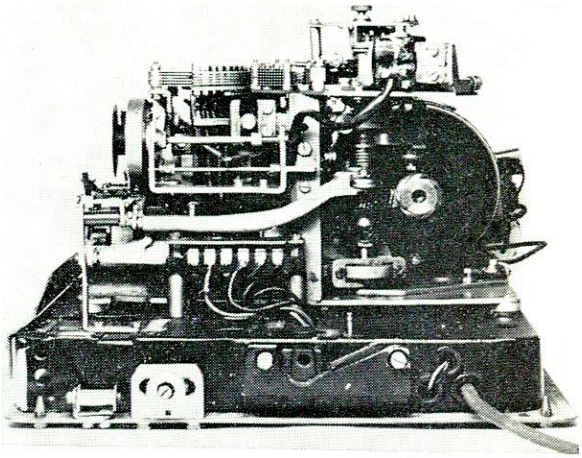
Motors

Some machines have synchronous motors and are generally unsuitable for use on other than a 60Hz supply.

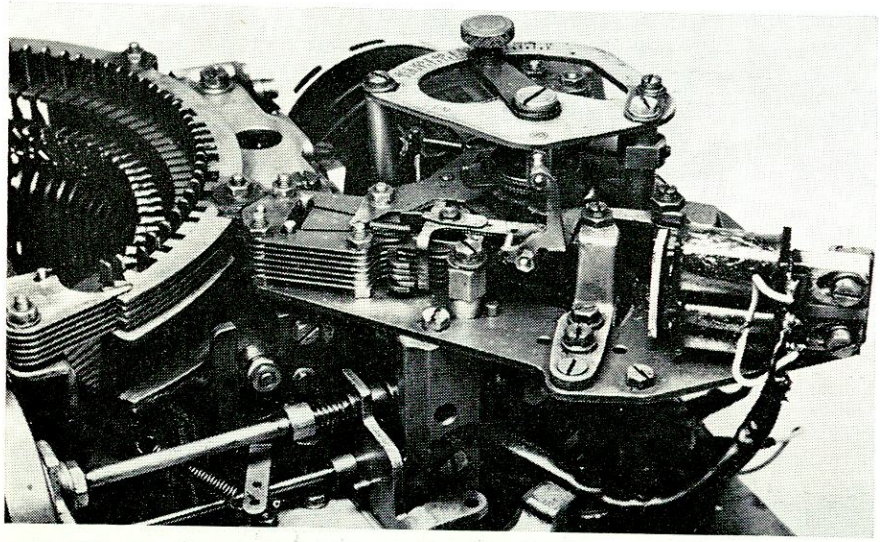
Others have governed series wound motors for use on ac or dc supplies.

N.B. The supply voltage is 110–120V. The governed motors have the governor mounted on the motor shaft opposite to the drive pinion.

It has stripes on its periphery such that, using a fork of 87·6V/s they will appear stationary at a transmitting speed of 45·6 bauds.



ABOVE.—The teleprinter Model 14 typing reperforator, showing punch operating lever.



LEFT.—The Teletype Model 14 typing reperforator showing electromagnet, rangefinder and code bars.

TELETYPE REPERFORATOR MODEL 14

Although the TT 14 appears in many forms it is basically one of two versions:

(*a*) The typing reperforator with or without keyboard.

(*b*) The non-typing, receiving only reperforator.

Reperforators are used to store teleprinter signals on punched paper tape so that they may be retransmitted later by means of a suitable tape reader such as the Teletype TD 14 or Creed 6/S.

In its most elaborate form the typing reperferator is fitted with a keyboard base. This enables it to:

(*a*) Receive signals and convert them to punched tape.

(*b*) Type the alpha numeric copy on the tape itself.

(*c*) Generate signals by the keyboard for direct transmission while simultaneously producing them as punched tape with the written record superimposed.

Without its Keyboard the TT 14 performs functions (*a*) and (*b*) above only.

The non-typing machine is much simpler and carries out function (*a*) above only.

Model 14 (FPR 17) Typing Reperforator

The complete instrument measures 17in × 16in × 12in and weighs 62lb. It has a cast base mounting the keyboard, tape holder and controls. The reperforator itself is mounted above.

The latter is a motor driven unit comprising the punch block mechanism as well as a typing head, with its ribbon feed for adding the alpha/numeric equivalent of the punched code on the tape.

All Model 14 reperforators can be equipped with either synchronous or governed motors and a would-be purchaser is well advised to ascertain the type before acquisition.

Synchronous motors are generally designed to give the correct speed with the gears provided when used on a 120V *60 cycle* supply. This means that when used on a *50 cycle* supply it becomes impossible, without cutting special gears, to achieve the correct speed.

Series governed motors can easily be identified by the target markings on the governor periphery which consist of alternate black and white segments. These governors have

the facility for speed variation and can be used on a 50 cycle supply. A fork of 87·6V/s for 45 speed is used.

Tapes produced by Model 14 are of the "chadless" variety for the following reason.

Messages recorded on tape by Model 14 reperforators appear both in typewritten characters and code perforations. Since the typed words and code occupy the same type area, complete perforation would remove part of the printing and reduce legibility. For this reason chadless tape is employed whereby the "chads" or punchings are not completely cut out of the tape, only three-quarters of the chad circumference is cut, leaving the rest as a sort of "lid" on the punched hole. This allows the tape to be used in a normal tape reader and gives enough area for the typed message. Chadless tapes can also be spliced easily without adhesive.

Operation

Two connections are necessary for putting Model 14 into service.

1. Suitable ac or dc supply depending upon the drive motor requirements. This is usually 115V 60 cycles for synchronous motors and 120V 25/60 cycles for governed motors. (Check name plate for rating.)
2. Connections for joining the operating magnet in the loop supply. The loop current through the magnet should not exceed 60mA and is designed for single current working. If the machine runs "free" on a "mark" signal in the loop; reverse the magnet connections.

Model 14 non-typing Reperforator

Performs the same operation as the typing version previously described with the exception that the type head is omitted and only punched tape is produced without alpha/numeric ciphers superimposed. It is thus a somewhat simpler machine. The instrument measures 17in × 17in × 14in and weighs 72lb. Motor types and ratings are as for the typing version.

The schematic for the TT 14 is shown in **Fig 3.16.** The selector magnet is described for single current 60mA loop conditions only. It is possible to operate the machine in a double current loop by the addition of a relay and sub-loop as shown in **Fig 3.17.**

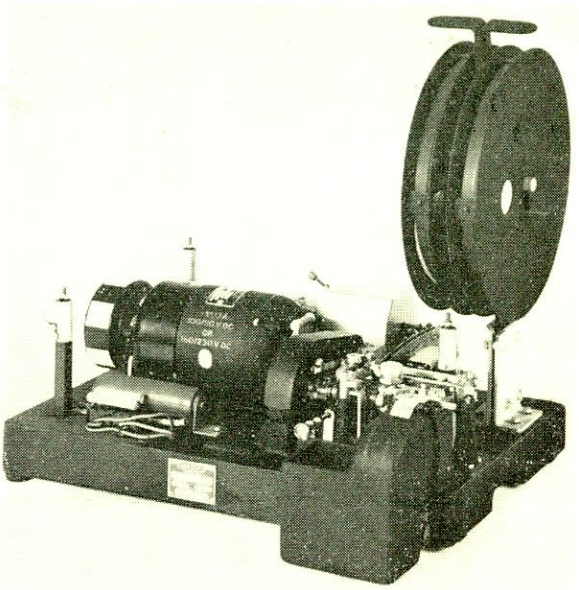
CREED 7TR REPERFORATOR

Manufactured by Creed & Co.

Height: 10½in. Length: 17in. Width: 15⅝in.

Weight: 35lb.

Consists of a main base on which are the following units: (*a*) driving motor, (*b*) receiving electromagnet, (*c*) selecting mechanism, (*d*) perforating head, (*e*) tape roll holder and (*f*) automatic start/stop switch. This machine will accept either 7 or 7½ unit signals and can be connected to a circuit to perform the following: (*a*) receive an incoming signal and instead of printing out the message it will provide a punched tape copy, or (*b*) may be connected in circuit with the keyboard of the printer and will give a tape copy. By suitable arrangement of the circuitry it is possible to be receiving a message on paper and at the same time the answer can be reperforated from the same machine.



The Creed 7TR3. This machine can punch two tapes simultaneously, hence the two paper holders.

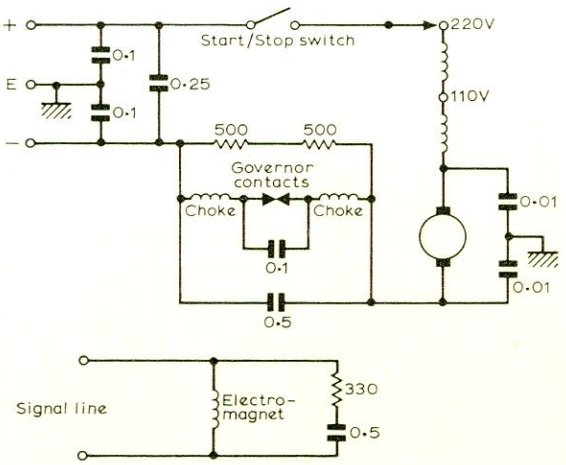
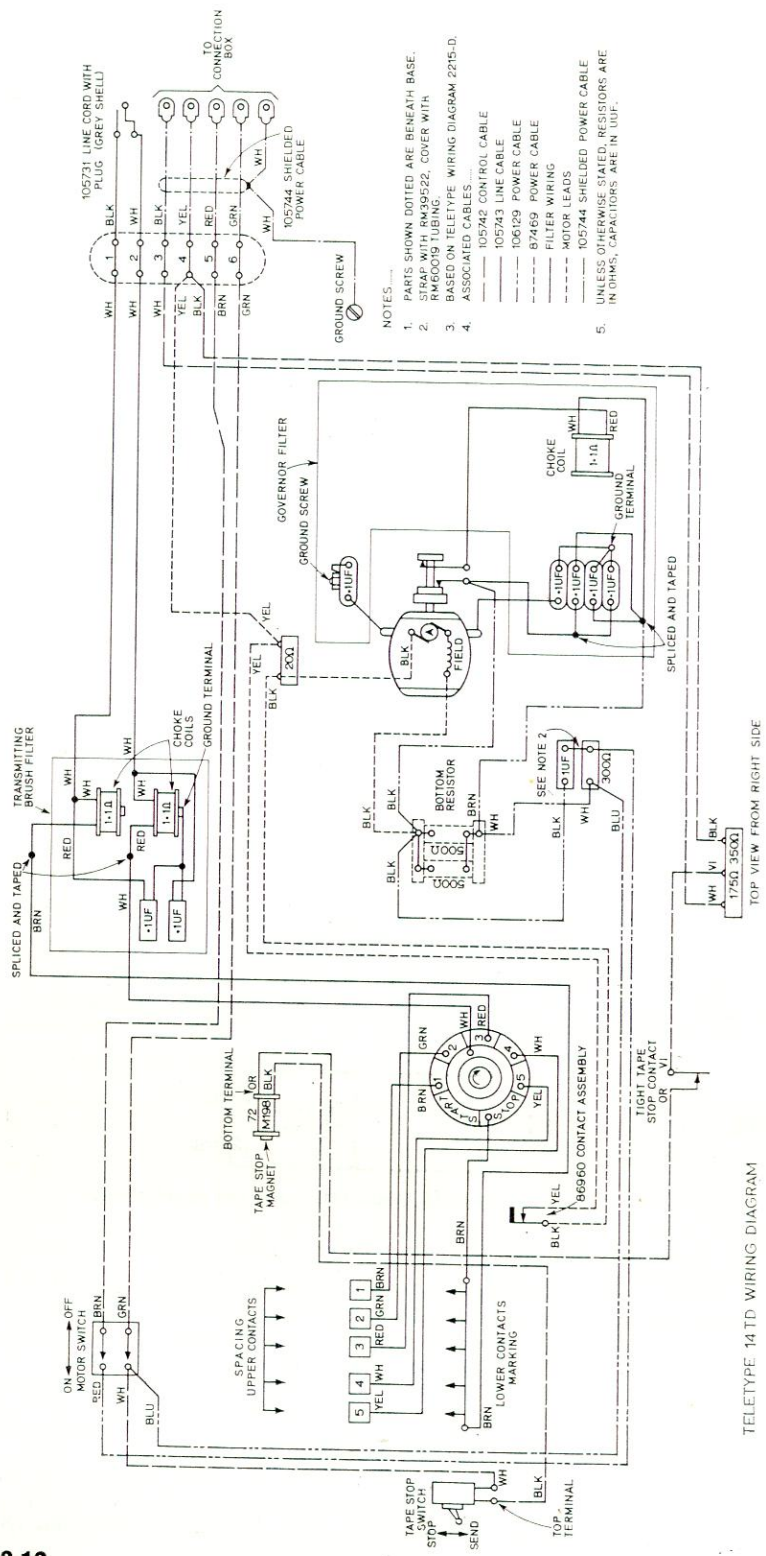


Fig 3.18. Creed 7TR motor and signal wiring.

Motors

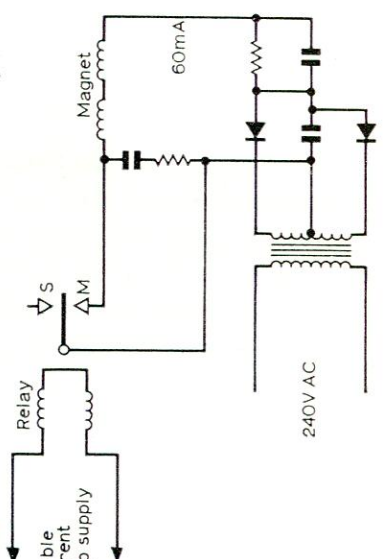
Similar types are used for this machine as the Creed 7B with their associate governors, the same speeds being used. The motor, however, runs in the reverse direction. The punches are positioned by means of an electromagnetic system, the magnet being the same and operated on the same principle as the 7B magnet. This also includes the automatic start/stop system. This has been described in the section dealing with the 7B teleprinter, to which the reader is referred.

Electrical connections consist of two leads, one for the motor supply and the other for the signalling system. If the latter has a nine-pin plug, only pins 3 and 5 are used, again as the 7B,



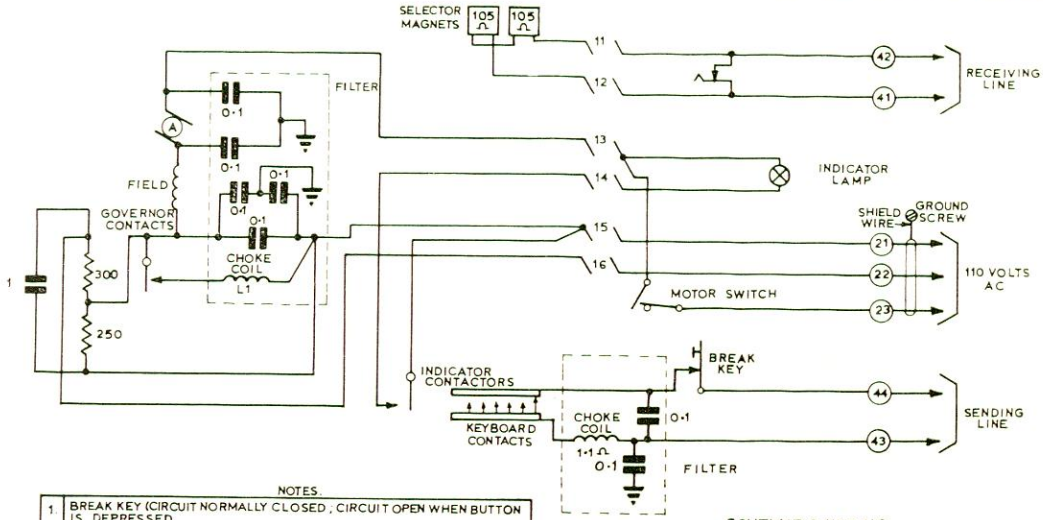
TELETYPE 14 TD WIRING DIAGRAM

ABOVE: **Fig 3.15. Teletype 14TD transmitter distributor.**



OPPOSITE PAGE: **Fig 3.16. Teletype Model 14 reperforator, wiring diagram.**

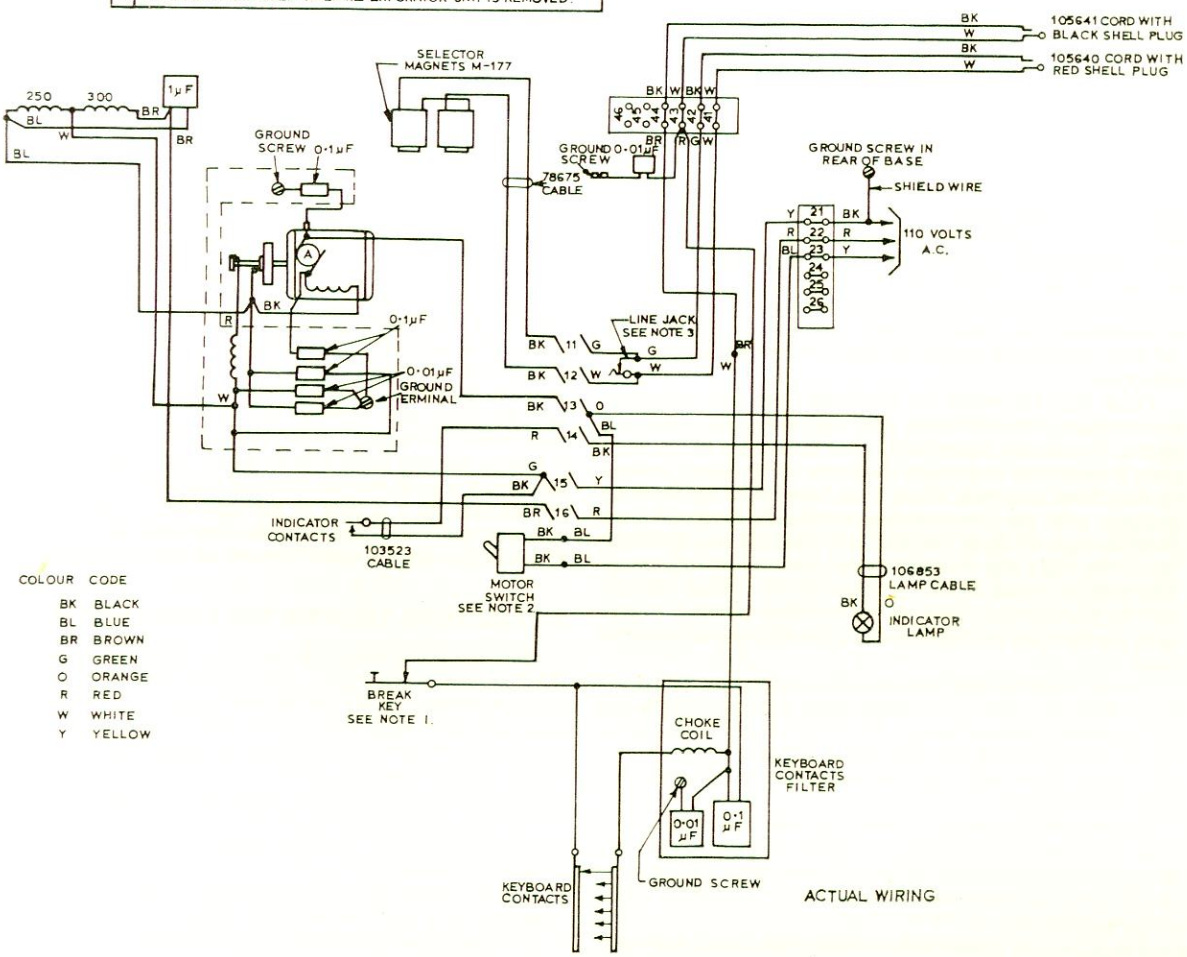
LEFT: **Fig 3.17. Teletype Model 14 reperforator, double current sub-loop.**



SCHEMATIC WIRING

NOTES.

1.	BREAK KEY (CIRCUIT NORMALLY CLOSED ; CIRCUIT OPEN WHEN BUTTON IS DEPRESSED.
2.	MOTOR CIRCUIT IS OPEN WHEN SWITCH IS IN UP POSITION, CLOSED WHEN SWITCH IS IN DOWN POSITION.
3.	LINE CIRCUIT IS CLOSED WHEN REPERFORATOR UNIT IS REMOVED.



ACTUAL WIRING

COLOUR CODE

BK	BLACK
BL	BLUE
BR	BROWN
G	GREEN
O	ORANGE
R	RED
W	WHITE
Y	YELLOW

for the current to the magnets. All circuits are suppressed for radio interference.

Receiving and Selecting Mechanism

The armature shaft from the electromagnet is coupled by a link to the trip shaft. Incoming signals will turn the trip shaft and set the hammer setting blade to take up one of two positions, ie raising it for marking elements and lowering it for the spacing elements.

When the selecting mechanism is actuated it operates in the same manner as that of the teleprinter 7B, but instead of positioning five comb setting fingers it positions five perforating hammers each of which is in line with a punch so that the tape is perforated in accordance with the signal received.

Rotation of the cam sleeve is dependent on a type of clutch similar to that used on the 7B, controlled by the pawl abutment actuated by the trip shaft. Receipt of the start signal causes the cam sleeve to commence to rotate and after one revolution it is checked by the stop signal actuating the pawl abutment which is set in the path of the pawls by the electromagnet being on the marking stop.

The cam sleeve has four tracks which control the selecting operations in the following manner:

Track No. 1 operates the hammer setting blade.

Track No. 2 operates the hammer re-setting lever, restoring the hammers to normal in readiness for the setting up of a new character.

Track No. 3 operates the traversing lever which is coupled to the traversing link and paper feed lever. This lever makes one cycle of movement for each revolution of the cam sleeve, during which the hammer setting pin carried by the traversing link is moved across the hammers in the following order: from hammer No. 3 to hammer No. 1 on receipt of the start element. From hammer No. 1 across to hammer No. 5 while receiving the code elements and back to No. 3 while the stop element is received. Movement of this lever also operates the feed lever which causes the paper to be fed forward $\frac{1}{10}$in each time.

Track No. 4 operates the punching lever and, therefore, the punching hammer frame, once per revolution of the cam sleeve. This occurs immediately after the setting of the hammers is completed and causes the frame to be moved forward so that those hammers, which have been set to the marking position, push the corresponding punches forward and force them through the tape. The feed hole punch is also operated, but direct from the hammer frame, for each combination. The hammer frame is then returned to its normal position and as this happens, slots on the operated punches engage with a projection on the frame and are withdrawn from the tape.

The perforating head consists of a casting on which are assembled the punches, die plates, paper feed mechanism and the punching hammer frame. The punches are supported in guide plates, behind one of which is clamped a set of three die plates into which the punches penetrate after passing through the paper.

The punching hammer frame is pivoted at its lower end and the five punching hammers together with their associated damping spring assemblies are positioned on a spindle fixed at the top of the frame, each hammer being associated with a code-hole punch.

The paper feed mechanism consists of the paper feed wheel

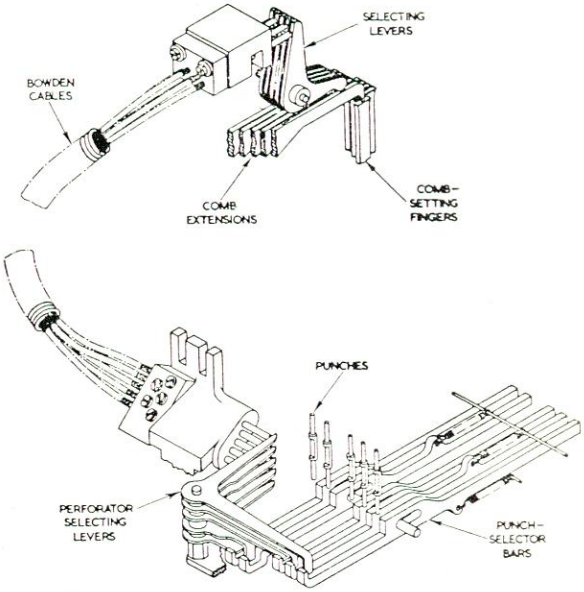


Fig 3.19. Diagram of perforator linkage, Creed 7B/RP

which engages with the centre feed holes in the paper and the feed ratchet, which is operated upon by the feed pawl and is provided with a retention roller. A hinged paper retaining plate is located over the paper feed wheel.

The $\frac{11}{16}$in wide paper tape is fed from the holder, along under the base of the machine, up the front and through the paper guide plates. If the tape is torn diagonally across it assists in passing up through the guide plates. (Where a machine has not been used for some time and there is a possibility that damp has affected it, remove the front guide plate, apply some thin oil and lightly scrape the plates with a razor blade as a small amount of rust will choke the clearance between the plates and the paper will not pass through.) Lay the paper over towards the front of the machine and close down the hinged paper retaining plate.

Just at the left hand side of where the paper leaves the machine is a push button. Pressing this will start the motor and as long as it is held in the tape will run through the machine but it will just have the feed holes punched in it. This will provide a "leader" for use on the auto transmitter.

THE 7B/RP TELEPRINTER REPERFORATOR

The 7B/RP is a telegraph machine, developed to perform the functions of teleprinter, reperforator and perforator. The basic machine is a Model 7B page teleprinter, fitted with a sawtooth keyboard, transmitter and answer-back unit as used on the Model 47 teleprinter and a perforating mechanism similar to that used on the Model 7P.

The machine provides the following facilities.

1. Normal teleprinter operation. The perforator mechanism is cut out by moving a perforator throw-out lever to the left.

2. Reperforator working, producing fully punched tape as well as a page printed copy. The perforator is brought into operation by moving the throw-out lever to the right.

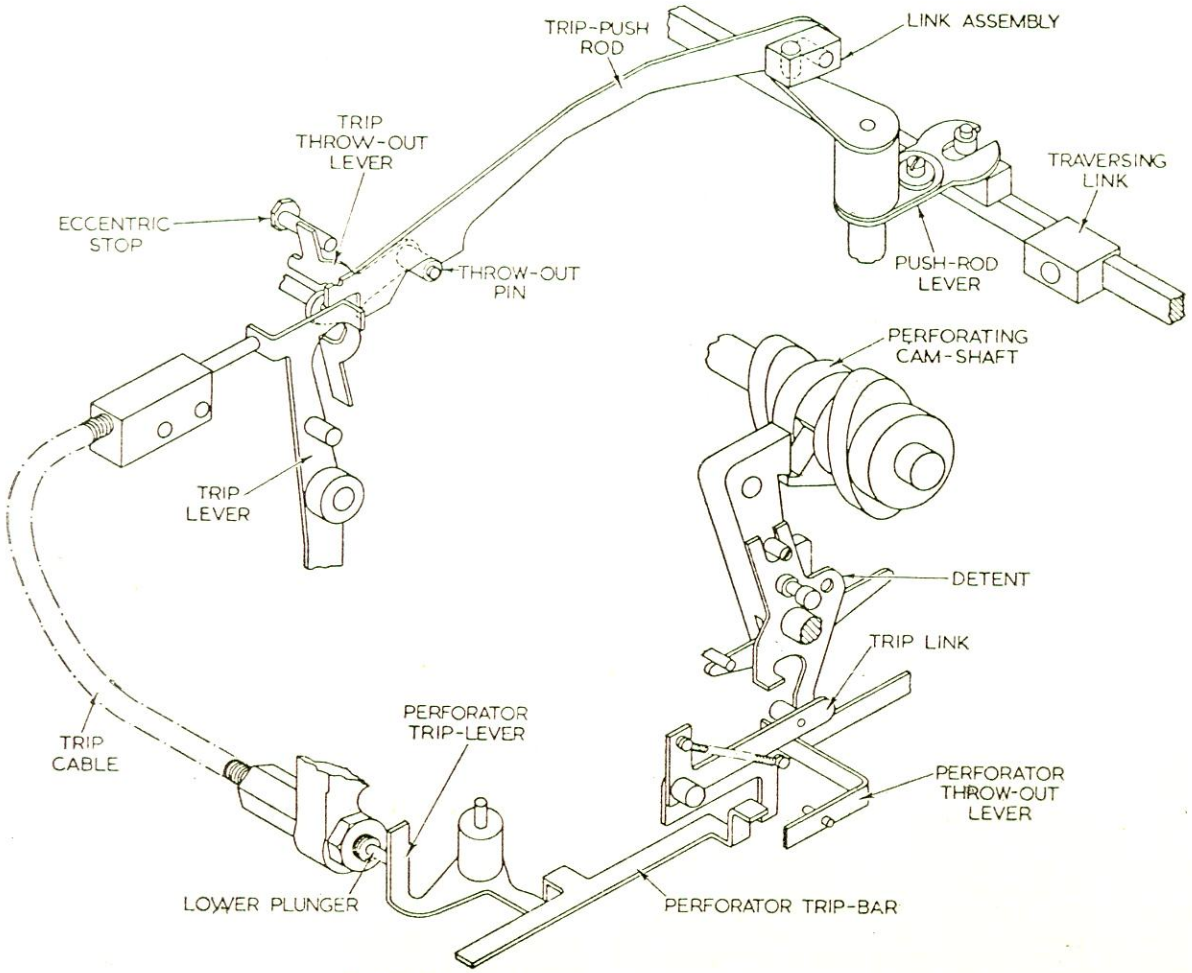


Fig 3.20. Diagram of perforator trip mechanism, 7B/RP.

Punched tape is made for all signals except "who are you?", "bell" and the "answer-back".

3. Perforator working, with no signal to line.

The perforator mechanism is mounted to the left of the keyboard and is controlled by a system of levers and Bowden cables from the combination head and an extension from the traversing link in the receiving cam-unit.

Perforator Mechanism

The perforator mechanism is set up for a particular code combination by transferring the settings of the comb extensions to the punch selector bars via levers and Bowden cables as shown in **Fig 3.19.** The punch-selector bars are spring tensioned to the right and through the perforator selecting levers and cables hold the selecting levers against the comb extensions. When a comb extension is lifted, the movement is transmitted through the levers and cable to move the punch-selector bar to the left. The anvil portion of the bar is then moved underneath the punch in readiness to punch the tape. If there is no comb extension movement the selector bar remains in its normal position and does not engage a punch.

Perforator Trip Mechanism

The perforator unit is initiated by the traversing link on the receiving-cam as shown in **Fig 3.20**. As the traversing link moves forward, the motion is transmitted via levers and the trip cable to a second trip lever located on the perforator unit. The perforator trip-lever moves the trip-bar to the right to release the detent from the pawls on the perforating cam-shaft. The cam-shaft rotates and operates the mechanism to punch the tape with the character set-up during the previous operation of the receiving cam-sleeve.

CREED 7B/RP

Procedure for Dismantling and Reassembly of Perforator Unit

Remove keyboard from machine, and, withdrawing two ch/hd screws from extreme ends of keyboard, note nylon coupling.
Remove keyboard cover, two screws.
Slacken hexagon headed screws on tape guide tube.
Remove tube.

To remove perforator unit from keyboard
Remove cuttings box.
Remove outer damping spring by inserting a spring extractor in the top loop of inner spring, take up the tension of the spring and withdraw spring anchor screw.
Remove cuttings box spindle and three guard plate csk/hd screws. Compress and remove outer spring.
Remove the three fixing screws from the rear of the keyboard casting.
Pull the upper end of the punch withdrawing bracket away from the punches and lift off the punch block unit carefully.

To remove anvil bracket
Remove two fixing screws, spring washers and plate washers, situated endwise on the casting and lift out. Place keyboard unit to one side.

To dismantle anvil bracket
Unhook back-space lever spring.
Remove clamping screw and withdraw spindle.
Remove back-space key assembly.
Remove locking collar from spindle of selector levers and lift off the selector levers in sequence.
Remove tape feed pawl assembly by withdrawing two ch/hd screws, the spring washers and plate washers.
Remove springs from punch withdrawing bracket.
Remove pivot screws from either side of punch withdrawing bracket. NOTE: Ensure that the eccentric spindle is locked before removal of pivot screws.
Remove punch withdrawing bracket.
Remove springs from Nos. 2 and 4 selector bars.
Remove guide pins.
Remove front circlip from selector bar locating pin and push out locating pin towards the rear of casting. Hold the selector bars to the left to facilitate removal of pin.
Remove selector bars Nos. 2 and 4.
Remove selector bars Nos. 5, 3 and 1, by lifting the left-hand end of selecting bars and sliding the springs from their anchor pin.
Remove spring from perforator throw-out lever (manual).
Remove locking collar from perforator throw-out lever.
Remove perforator throw-out lever (manual).
Remove locking collar from perforator trip lever.
Remove perforator trip lever. NOTE: Observe felt lubricating pad.

Reassembly of anvil bracket assembly.
NOTE: Before proceeding to assemble the unit remove any paper chads, surplus oil and grease from unit.
Replace perforator trip lever to engage with the perforator trip bar.
Replace locking collar and ch/hd screw. *Check for freedom of movement.*
Replace perforator throw-out lever (manual).
Replace locking collar and ch/hd screw. *Check for freedom of movement.*
Anchor tension spring.
Replace selector bars Nos. 1, 3 and 5 by first placing the springs on anchor pin and positioning selector bars in their respective guides.
Replace selector bars No. 2 and 4 in their respective guides.
Replace selector bar locating pin by inserting it at the rear of casting.
Replace front circlip.
Replace selector bar guide pins.
Replace selector bars Nos. 2 and 4 springs on near guide pin.
Replace withdrawing bracket, two shouldered screws ch/hd.
Replace two tension springs on anchor pins on both sides of the punch withdrawing bracket.
Replace tape feed pawl assembly, two ch/hd screws spring washers and plate washers.
Replace back-space key assembly complete with spindle and retaining bracket one ch/hd screw and washer. NOTE: Position back space pawl *beneath* the stop pin on tape feed pawl.
Replace back space pawl spring on its anchor.
Replace selector levers, ensure that they engage with the selector bar extensions.
Replace locking collar one ch/hd screw. NOTE: *Check for freedom of movement.*

Dismantling the perforator unit
Punch block assembly
Remove cuttings chute by slackening two ch/hd screws.
Remove punch block assembly by withdrawing two ch/hd screws between chute and tape roller. Place cam-assembly to one side.
Remove latch spring (light).
Remove latch, one clamping unit, spring washer and plate washer.
Remove tape guide frame spring (heavy).
Remove tape guide frame (two pivot screws). NOTE: Distance washer between frame and assembly on front of casting.
Remove punch cover plate two ch/hd screws.
Remove two die plates in sequence, tape guide plate then four die plates.
Lift out the five punches and the feed hole punch in order. NOTE: Reassemble the punches in the correct manner, narrow shoulder to the bottom.
Remove the four lower punch-guide plates, two ch/hd screws.
Remove latch support plate, two ch/hd screws beneath casting.
Remove tape "tear-off" stripper spring, two ch/hd screws on side of casting. Lift off gently to avoid damage to spring mounted on casting.
Remove bearing blocks, two ch/hd screws on either side of block.
Remove tape feed spindle from bearing blocks.

Reassemble punch block assembly
Clean casting of chads, surplus oil and grease.
Replace tape feed spindle together with the two bearing blocks on the casting.
Replace screws in the bearing blocks and tighten. NOTE: *Check for freedom of movement.*

Replace tape "tear-off" spring and its pivot screws. NOTE: *Check for freedom of movement.*

Replace latch support plate, two ch/hd screws.

Replace four upper die plates, tape guide plate, two die plates and punch cover plate two ch/hd screws.

Replace punches in correct order narrow shoulder at the bottom.

Replace four lower guide plates. NOTE: *Check for freedom of movement.*

Replace tape guide frame, two pivot screws. NOTE: Distance washer to be placed between casting and the frame on front. *Check for freedom of movement.*

Replace latch, eccentric screw, plate washer, spring washer, and nut.

Replace latch spring.

Replace tape guide frame spring.

Dismantling of cam-assembly

Remove triangular front plate four nuts and washers. NOTE: Shims are fitted between the front plate and cam-shaft.

Remove two distance locking collars from the detent pillars.

Remove the detents by turning the cam so that the upper cam roller is raised clear of the left-hand detent.

Release retention pawl springs from their anchor pin.

Remove retention pawls, one nut and washer and eccentric bushes.

Remove cam and cam-shaft, from its rear bearing.

Remove cam from its shaft by pressing the pawl backwards against its spring and withdraw cam.

Remove locking collar, which retains the punch block casting on its spindle.

Remove punch block casting.

Remove spring on the retention lever on punch block casting.

Remove retention lever.

Remove retention lever adjusting plate and its eccentric, one ch/hd screw, plate washer and spring washer.

Slacken the locking nuts on the detent stop and withdraw stops.

Reassembly of cam-assembly

NOTE: Before assembling the unit, clean the casting of chads, surplus oil and grease.

Replace detent stop.

Replace retention lever adjusting eccentric.

Replace retention lever.

Replace retention lever spring.

Replace punch block casting on its pivot.

Replace locking collar on spindle. NOTE: *Check for freedom of movement.*

Replace cam on its cam-shaft.

Replace cam and cam-shaft in rear bearing. NOTE: Gear wheel towards rear.

Replace rear eccentric for retention pawl. NOTE: Nut of eccentric bush to rear of casting.

Replace rear retention pawl on eccentric bush, add washer, and front retention pawl, eccentric bush. NOTE: Nut of eccentric bush to face frontwards.

Replace plate washer, spring washer and nut.

Replace springs on retention pawls. NOTE: Check retention pawls for freedom of movement.

Replace detents.

Replace two locking collars on detents.

Replace front plate. NOTE: Shims fitted between cam-shaft and front plate.

Replace four sets of nuts, plate washers and spring washers.

Fix cam-assembly to punch block assembly by replacing two ch/hd screws between cuttings chute and tape roller.

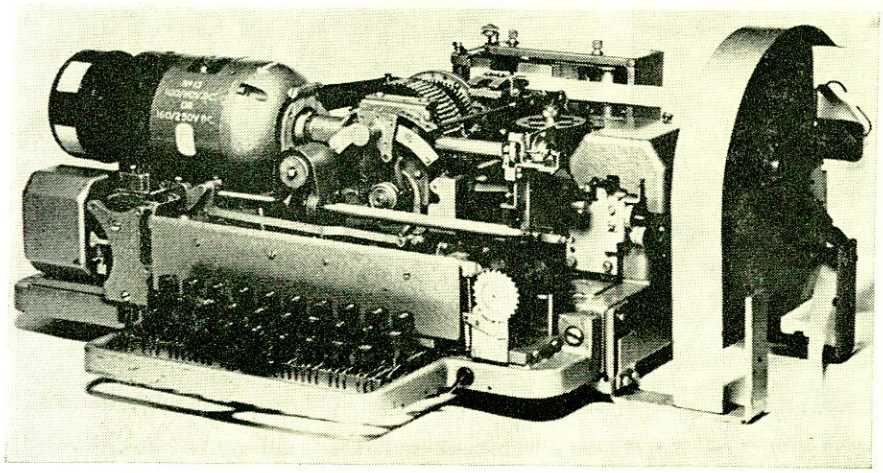
THE 85R PRINTING REPERFORATOR

The 85 printing reperforator provides a printed as well as a perforated record of incoming messages on standard size teleprinter tape.

This is achieved by superimposing the printing on the perforations, legibility being preserved by arranging that perforations are incompletely cut leaving hinged lids which are bent back flush with the surface of the tape.

The basis of the machine is the No. 7 teleprinter to which some modifications have been made to provide the new requirement. The perforator unit and control unit replace the page attachment and lever units.

Five new types have been added to the typehead, ie "who



Creed Model 85R printing reperforator.

are you", " carriage return", "bell", "line feed" and "all spacing." Every perforated combination is printed leaving the operator in no doubt of the exact message.

Principle of Operation

The main difference between the 85R and the No. 7 teleprinter is that the page attachment unit and functional levers have been replaced by a perforator. On the No. 85 reperforator a separate chain of actions causes the code setting on five vertical comb setting fingers being reproduced by a special transfer mechanism, five horizontal punching bars on the perforator unit cause the combination to be punched in the tape.

Transfer Mechanism

Resting in V-shaped slots cut in the five comb extensions and supported by brackets fixed to the combination head are five vertical selector push rods. Viewing the machine from the front these support the forward ends of five rectangular frames, the transfer rockers, mounted one inside the other on a rod passed through their centres. The rear ends of these rockers rest upon the transfer push rods.

These rods stand upon the ends of the bellcranks which under the action of springs are moved on a pivot pressing upon setting arms. These have their upper ends shaped into jaws through which run the horizontal punching bars.

When the marking fingers are raised by the comb-setting lever the transfer rockers are rotated, and in turn depress some of the transfer rods. The bellcranks affected turn about their pivot, motion being passed via springs to the setting arms. Therefore the raising of the marking fingers on the combination head causes the displacement of corresponding punching bars on the perforator unit in a forward direction.

As the action of setting the punching bars is controlled basically by the comb-setting lever, it takes place almost at the end of the receiving cam sleeve revolution. Therefore, like printing, perforating takes place during the next revolution of the receiving cam.

Punch Unit Dismantling Instruction

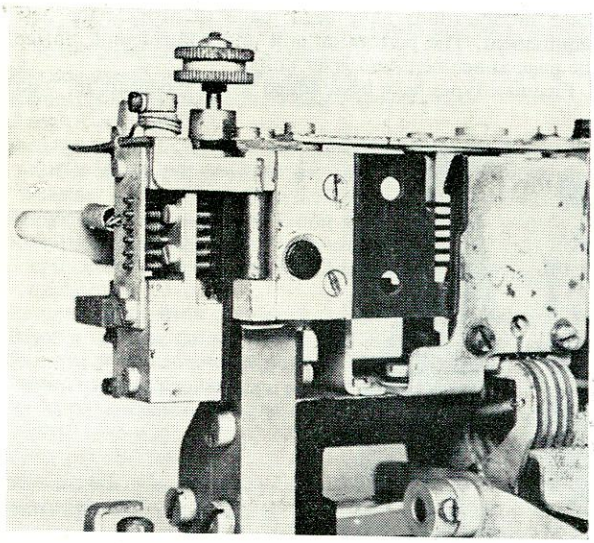
1. Remove punch unit from drive unit, three screws from side, one screw from top, turning slightly to disengage punches from associated punch bars.
2. Remove pressure arm latch and rat trap spring, one locking collar. NOTE: Shim beneath latch.
3. Remove pressure arm spring.
4. Slacken locking collar and remove pressure arm complete with rollers.
5. Remove platen retaining plate, two csk screws.
6. Remove platen.
7. Remove platen holder plate, two screws.
8. Remove one or more shims, plus thick steel platen.
9. Remove punches.
10. Remove punch die block, two screws. NOTE: On new type, one screw and two hexagonal nuts.

NOTE: All die plates, guide plates, punching bars and punches are in complete sets and must not be changed as individual items.

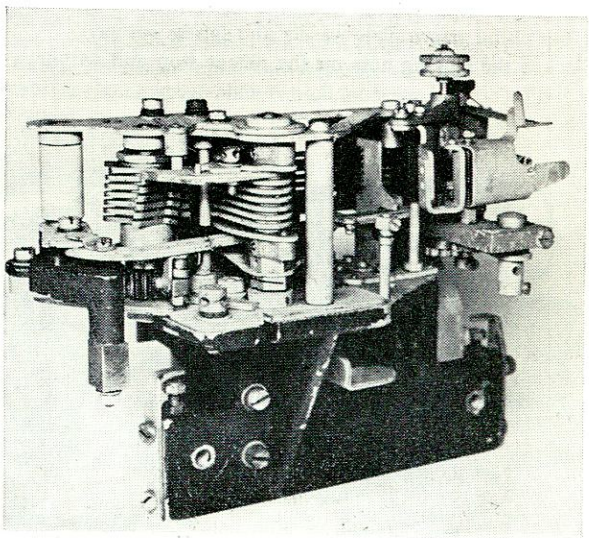
11. Remove jockey roller spring, locking collar and jockey roller.

Punch Unit Reassembly Instructions

1. Replace die plates and die block.
2. Replace punches. NOTE: Third from top is feed hole punch.
3. Ensure that all punches are perfectly free. To check this, loosen the die block, then press the backs of all the



Creed 85R perforator assembly, front view showing rubber type platen (centre)

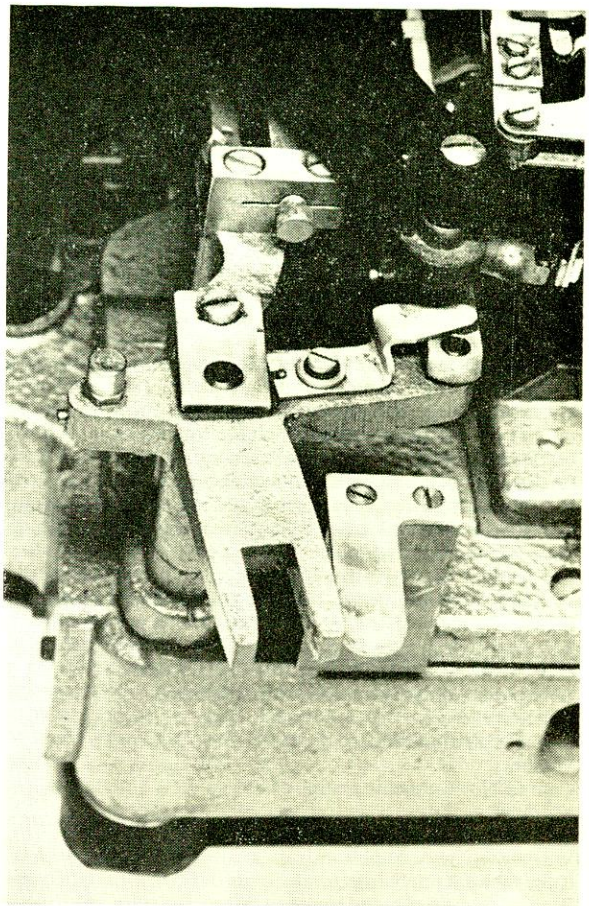


Creed 85R perforator assembly, rear view.

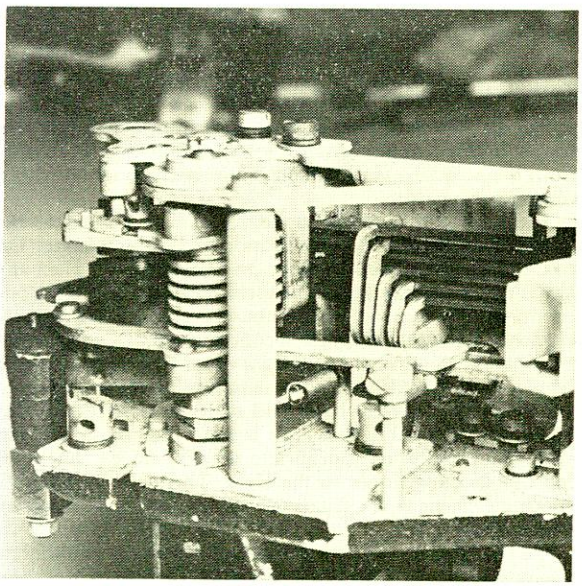
punches on the bench so that they pass through the die plate. Hold them in this position while tightening the fixing screws on the die block.
4. Replace steel platen and shims.
5. Replace platen holder plate.
6. Replace platen and platen retaining plate.
7. Replace complete pressure arm, locking collar and spring.
8. Replace pressure arm latch, spring and locking collar. NOTE: One shim.
9. Replace jockey roller, locking collar and spring.

Drive Unit Dismantling Instructions

1. Remove setting arm guide plate, two screws, slacken only.
2. Remove triangular top plate, three screws. NOTE: Shims on two spindles possibly.
3. Remove distance collar from feed lever spindle.
4. Slacken tape feed pawl retaining plate and swing clear.
5. Remove tape feed pawl adjusting plate from feed lever, one screw.
6. Remove feed lever, two screws. NOTE: Washer on lower part of feed lever spindle.
7. Remove cam feed sector.
8. Slacken locknut and screw on resetting lever and move clear of cam.
9. Remove tape feed pawl spring and retention lever spring.
10. Remove punching camshaft complete with feed pawl and pinion.
11. Remove tape feed pawl extractor, two screws.
12. Remove tape feed pawl spring pivot. NOTE: On new machines, it is held by a circlip.
13. Remove pawl guide pin, one screw.
14. Remove tape feed pawl.
15. Turn punching levers anti-clockwise and resetting lever clockwise, then lift off complete assembly. Note position of any shims fitted.
16. Remove punch bar right hand guide bracket, two screws.
17. Remove punch bars. NOTE: Feed punch bar is third from top and is marked with a "C".
18. Remove setting arm and bellcrank assembly, two screws.
19. Disconnect all bellcrank springs.
20. Remove setting bellcrank guide, two screws.
21. Remove WRU suppression lever.
22. Remove locking collar.
23. Remove bellcranks and setting arms. NOTE: Distance shim at rear of spindle.



Creed 85R showing the punch operating lever.



Creed 85R perforator assembly, showing perforator operating bars at centre.

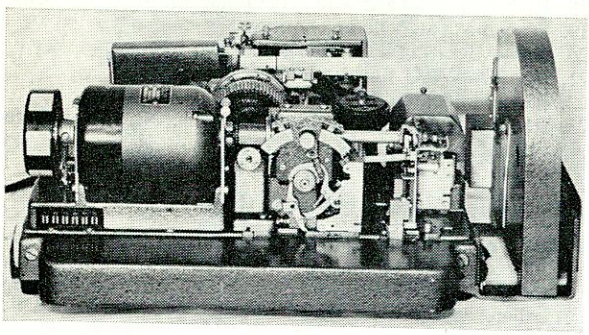
Drive Unit Reassembly Instructions

1. Assemble the setting arm and bellcrank assembly complete. NOTE: The longest setting arm is associated with the shortest bellcrank and goes on first, after the distance collar.
2. Fit the setting arm and bellcrank assembly against its fitting abutments and screw to main unit.
3. Replace the punching bars.

4. Replace the right hand punching bar guide bracket.
5. Replace punch unit and engage punches with punching bars.
6. Replace punching lever and resetting lever assembly. NOTE: Punching levers behind punching bars, resetting lever in front of punching bars. Replace any shims that may be below this assembly.
7. Replace tape feed pawl.
8. Replace tape feed pawl spring pivot.
9. Replace tape feed pawl extractor.
10. Replace punching cam assembly with feed pawl and pinion.
11. Replace cam feed sector. NOTE: Ensure that cam feed sector engages correctly with the teeth on the cam feed pawl.
12. Replace feed lever. NOTE: Also spacing washer below lever.
13. Replace tape feed pawl adjusting plate, ensuring that the pin on this plate engages the tape feed pawl.
14. Replace the tape feed pawl retaining plate.
15. Replace distance collar on feed lever spindle.
16. Replace tape feed pawl spring and retention lever spring.
17. Replace triangular top plate, ensuring all shims are on their respective spindles.
18. Replace setting arm guard, ensuring that there is a very small gap between the guard and the setting arms.

Cam Sleeve (Pinching) Assembly

Hexagonal clamping nut (6BA box spanner)
Washer
Cam H resetting cam.
Washer
Cam G No. 1 punching cam.
Washer
Cam F No. 2 punching cam.
Washer
Cam E No. 3 punching cam.
Washer
Cam D No. 4 punching cam.
Washer
Cam C No. 5 punching cam.
Washer
Cam B No. 6 punching cam.
Large distance piece
Feed ratchet "A"
Washer



The Creed 86R. This unit is similar to the model 85 but has no keyboard

NOTE 1: All cams to be replaced, when assembling, with the stamped code letter visible commencing with "A".
NOTE 2: When commencing reassembly, fit first distance washer and replace key so that it rests on the distance washer and does *not* engage with its keyway. This will ensure that the key does not slip during reassembly and that there will be sufficient key extending to locate cam H.
NOTE 3: The punching and resetting lever assembly. The shims fitted to this assembly are not in a set order. The shims govern the positions of the various levers including the cam retention lever with respect to their respective cams. They should be fitted to ensure that all these levers bear in the centre of their cam profiles.

THE TYPE 44 KEYBOARD PERFORATOR

The Type 44 Keyboard Perforator is almost unique amongst teleprinter apparatus in that it does not contain a motor of any description, all power being supplied by a solenoid. The machine appears in two versions, the Mk 1 and the modified mass-produced Mk 2. The two models differ mainly in the construction of the combination bars and the letter counter and in the location of the resistances in the base.

The machine is keyboard operated and depression of any key operates a number of combination bars which determine the punching to be made. When the key is fully depressed, a circuit is completed and energizes the electromagnet whose armature operates the punches selected. When the key restores, the circuit is broken and the armature restores; in so doing it causes the tape to be fed forward ready for the next punching. The machine uses plain $\frac{11}{16}$in tape from a reel mounted on a spinner at the back of the lectern and punches its own centre holes. A letter counter is provided so that the machine can be used with page printing receiving equipment. This counts the characters typed and lights a lamp as the end of a line is approached. When the "carriage return" key is depressed it restores the counter to zero.

Technical Description

The machine is designed to operate from a 110–250V dc supply and consumes $\frac{1}{2}$A. It may be operated satisfactorily from the ac mains via a silicon diode in conjunction with a reservoir capacitor.

The keyboard is of the standard layout as fitted to the Teleprinter 7B, but on Mk 1 models is non-locking. On Mk 2 models it is semi-locking. On Mk 1 models, when any key is depressed, the key bar associated with it depresses one or more of the five combination bars, according to the signal elements of the character. Each combination bar is supported by a parallelogram linkage from a pivot block on the right-hand side of the machine. A combination bar when depressed pushes down the right-hand end of its associated selecting lever. The left-hand end rises against the tension of its spring and rotates its appropriate selecting finger, thus moving the selecting finger to the right. This corresponds to a spacing element in the character and no hole is punched for these elements.

On the Mk 2 models the combination bars are of different design and, when a key is depressed, the key bar moves them sideways on rollers instead of vertically. The selecting levers in this case bear on the ends of the bars. No selecting lever

The Type 44 keyboard perforator.

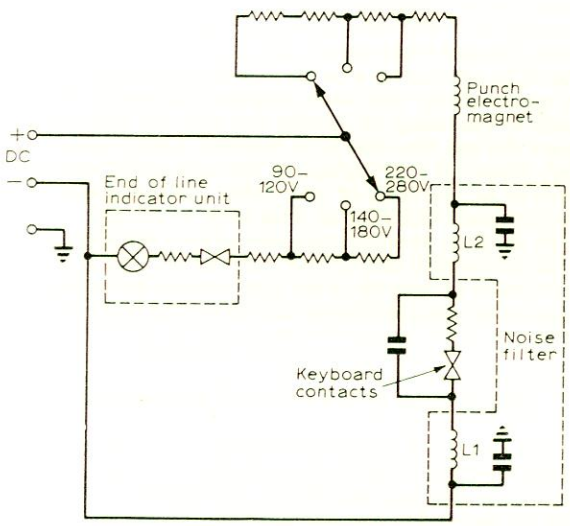


Fig 3.21. Circuit diagram of Model 44 keyboard perforator.

tension springs are fitted as the levers and combination bars restore by the action of the selecting finger tension springs and the action of the next key lever.

The Punching Head

This is mounted to the left of the machine and is arranged so that the punches punch vertically upwards. The six punches (five signal element and one feed hole) are spring loaded downwards. The ends of the selecting fingers in their normal (to the left) position lie just underneath the appropriate punches. The selecting levers are also spring loaded downwards and are kept in their correct positions by a comb-shaped guide plate. When the electromagnet is energized it turns the armature spindle and forces upwards the hammer arm coupled to it. The hammer face strikes the end of these selecting fingers which are normal (to the left) forcing them and the punches upwards, thus punching the tape with the required code. The feed hole punch is operated by the hammer face every time a code punching is made, so that feed holes are always punched. The hammer lever is integral with an arm on which is mounted the tape feed pawl. On the release movement of the armature spindle this pawl engages in the paper feed ratchet wheel, turning the paper feed star wheel one tooth and feeding the paper forward by one feed hole ready for the next punching. The "back space" key is mounted on the left of the punching block. When depressed, it trips the tape feed pawl, and the back space pawl mounted on the back space key bar turns the tape feed star wheel backwards by one tooth. This key is used for erasures, the procedure being to back space and then over-punch the unwanted punching with "letter shift", ie five holes in the tape.

Removal of Punches

Under normal conditions, and provided the punch block is carefully adjusted during assembly (see later), the cutting edges of the punches and die plates should have a very long life. When, due to bad punching, it becomes necessary to renew the punches, the punch block should be removed as follows:

Unscrew the four large screws which hold the punch unit to the main casting, and remove it complete. Take out the two large screws holding the punch block to the punch unit main casting, and lift it off the punch block. Unscrew the two large screws holding the hammer shaft bearings, and take off the half bearings. Lift out the hammer assembly. The method of dismantling the punch block is obvious. Note, however, that it is essential that the five selecting fingers and their spacing washers are kept in the same order during the dismantling and reassembly of the punch block, so that they always go back into their original positions. To remove the punches without dismantling the block, pull out the punch restoring springs and the punches will be free to fall out.

The ends of the punches are hollow ground and all signal hole punches must be of similar length. It is, therefore, not intended that the punches shall be resharpened, but replaced, and the old set scrapped.

Punch Block Reassembly

Place the punches in their correct holes in the block and fit the punch restoring springs. Bolt on the restoring spring

adjusting plate, fixing it so that, when the punch guide plate is fitted, the heads of all the punches will be just below the top of the guide plate. Fit the paper feed star wheel on its spindle. Fit the jockey roller assembly. Remove the punch restoring springs temporarily. Fit the lower punch guide, the two copper distance pieces and the die plate above. These must assemble so as to form a tapered mouth, into which the paper tape will feed. Push the punches well into the die plate before tightening the fixing screws. This ensures that the die plate and punches are in perfect alignment, which is most important, as it greatly affects the useful life of the punches. When every punch can move easily and freely through the die plate, the punch restoring springs may be replaced. Check that these springs withdraw the punches smartly and that the ends of the springs engage correctly with the retaining plate. Great care in fitting the punch block together is most important, as it is the biggest single factor affecting the performance of the machine. Fit the paper guide and the knife edge if these have been removed.

Letter Counter

The letter counter on the more commonly met Mk 2 versions consists only of an "end of line" alarm lamp which lights when about 56 characters have been typed. There is no dial or other indication of the actual number of characters typed since the last operation of the "carriage return" key; it may be noted that the counter does not distinguish between printable characters and figs/letters shift characters.

The method of operation is reasonably obvious. The operate lever is thrust towards the right by an extension from the electromagnet armature each time the punch hammer restores to normal after operation. This movement actuates the feed pawl, causing it to feed the ratchet wheel round by one tooth. While the next letter is being punched, the ratchet wheel is held stationary by a retention pawl. After 54 operations the stop stud on the ratchet wheel bears on the contact operating lever, and this, via the ebonite roller at its end, will actuate the alarm lamp contacts.

When the operator depresses his "carriage return" key, in addition to punching the tape, levers lift the retention pawl. This permits the ratchet wheel to spin back under the action of its return spring.

Lubrication

A little thin oil should be applied sparingly to the bearings of the keys and combination bars and the moving parts of the punch block. Never oil the cutting ends of the punches but a little applied at the point where the restoring spring enters the punch helps to reduce wear. Keep oil applied to the punch at a minimum as excess oil collects paper cuttings and fluff which clog the mechanism.

Insertion of Paper

The paper roll should be placed on the paper wheel so that the paper unwinds freely in a clockwise direction. The edge of one side of the end of the paper tape should then be cut away to form a wedge shaped end. This end should be threaded through the guide bar, die plate and paper knife and then gently pulled over the paper feed star wheel. The machine should then be operated under power by tapping the space bar, and the paper eased gently until it is fed by the pins of the star wheel. It may be found desirable, in some instances where the star wheel tears the paper, not to allow the machine to pull paper directly from the reel, but to keep a free loop of paper before the punch block and allow it to draw from this.

Adjustments

Tape Feed

The tape feed should be such that the perforated tape is moved forward $\frac{1}{10}$in for each character. For reliable operation the feed should be regulated by means of the tape feed jockey roller, so that one centre hole coincides with each $\frac{1}{10}$in division of a steel rule. The position of the jockey roller is controlled by means of two cheese-headed adjusting screws, located just behind the paper guide. To increase the distance between centre holes the right-hand screw should be gradually withdrawn and the left-hand one screwed in by a corresponding amount, until the tape feed is correct; to decrease the distance this procedure is reversed. Both screws should be left tight but not over-strained.

Punch block

The punch restoring springs should withdraw the punches smartly from the die plate. Correct tension should be obtained by setting the straight portion of the spring at a point approximately $\frac{3}{8}$in from the right-angled bend. The end of the spring which engages in the hole in the punches should be kept straight, and not set upwards or downwards, as by doing this the position of the punches will not be uniform when they are in their rest position.

The punch spring retaining plate should be adjusted so that the punches when in the normal position are just below the level of the punch guide plate.

Punching Magnet

Two pairs of set-screws are provided for adjustment purposes. One pair (at the left-hand end of the main casting) controls the armature travel, and the second pair (immediately behind the punch block) adjusts the coupling between the armature and punching unit. The lower screw in the main casting should be adjusted to produce a clearance of approximately 5mil between the pole faces and the armature when operated under power. The armature coupling screws should be adjusted to cause the punches to enter the dieplate by approximately $\frac{1}{64}$in when operated. Adjustment may be made by slackening the locking nuts and then screwing one screw out and the other in as required. Finally screws and nuts should be fully tightened. The adjustment should be checked by operation of the "letters shift" key and when correct should cause the six holes to be cut cleanly.

By using the armature back-stop adjustment (upper screw under left-hand of casting) lower the hammer lever to provide a clearance of approximately $\frac{1}{32}$in between the underneath edges of the selecting fingers and the surface of the hammer face.

THE CREED 7P KEYBOARD PERFORATOR

The Model 7P keyboard perforator is a motor driven machine designed to make a fully punched five-unit perforated tape from $\frac{11}{16}$in wide parchment. The motor fitted may be either a four-pole induction motor running at 1,450rpm or a series-wound dc governed motor running at 1,500rpm.

The keyboard and character counting mechanism fitted to this machine are very similar to those fitted to the Creed Model 47 tape teleprinter, and the punch assembly is similar to that used on the Model 7B/RP.

Keyboard

Contained within the keyboard mechanism are five combination bars, one for each of the five code elements, and one trip bar which when operated releases a detent latch in the control unit and so allows the machine to punch a character. The combination bars, which are notched to correspond with the code elements, move to the left for the space elements or remain stationary for the mark elements. Coupled to the ends of the combination bars via levers which reverse the movement, are the selector bars, the function of which is to set up the punch combination.

Perforator

The perforator or punch mechanism is made up of two units, the anvil bracket and the perforating unit. The anvil bracket is fixed to the keyboard casting and holds the selector bars which are free to move from side to side underneath the punches. If a key is depressed, the selector bars corresponding to a space are moved to the right. The amount of movement is such that the end of the bar is withdrawn from beneath the end of the appropriate punch. The mark bars remain underneath their punches.

The perforating unit is built up on the punch block, and holds the main items of the assembly. These are the punches and their associated die plate, the paper feed wheel, and the operating and restoring cam followers. The punch block, which is pivoted to allow a see-saw action, is driven by two cams mounted on a common shaft, controlled by the perforator control unit. The operating cam causes the punch block to be moved in an anti-clockwise direction and then it is returned to its original position by the action of the restoring cam. As the punch block is moved anti-clockwise, the punches are moved towards the selector bars. Where a mark is to be punched in the paper tape, the selector bar is in such a position as to prevent any further downward movement of the punch and thus, as the whole punch block continues to be driven by the operating cam, the punch is forced through the tape into the die plate, so perforating a code element. Where a space code element is required, the selector bars are moved sufficiently to the right of the punches so as to allow the punches to continue movement with the punch block and so not be driven through the tape.

After the anti-clockwise punching movement, controlled by the operating cam, the punch block is operated in a clockwise direction by the restoring cam and the punches which have moved are withdrawn by the action of the punch-withdrawing bracket, mounted on the anvil bracket.

The operating and restoring cams are arranged so that there are two operations for each revolution of the shaft. Because of this, the maximum punching speed is approximately twice that of a standard teleprinter.

Perforator Control Unit

The operation of the perforator control unit is initiated by the action of the trip bar movement on the keyboard. The movement of the trip bar to the left, caused by the operating

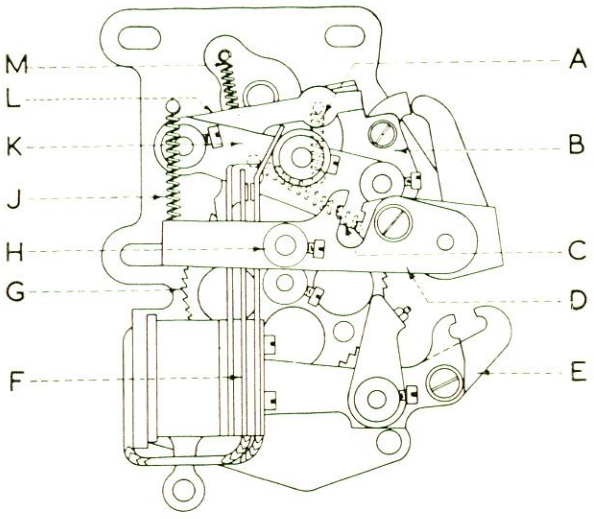


Fig 3.22. Perforator operating unit. Indicator letters are those used in the Creed Instruction Booklet No 67N (2nd edn).

of a key, allows the trip lever to turn the detent operating lever, which in turn controls the clutch ratchet via a release latch. The two parts of the clutch are driven together under the influence of a coil spring and turn the control cam shaft clockwise.

When the control cam shaft has rotated through a quarter of a turn the resetting cam engages with the detent release latch. The latch is turned on a pivot, disengages from the detent operating lever and so stops the anti-clockwise movement of the detent-control shaft. The tension spring on the trip detent then pulls the detent in a clockwise direction

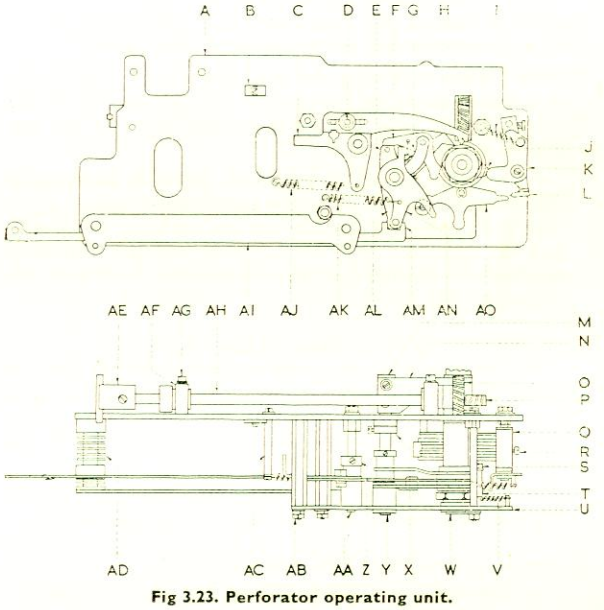


Fig 3.23. Perforator operating unit.

and a peg on the end engages with the radial cam surface on the clutch ratchet, so disengaging the clutch.

On the control cam shaft is mounted the perforator release cam which has a lever following the cam profile. This lever is pivoted centrally and the lower end engages the perforator operating bar which releases a clutch on the perforator unit so allowing the operating and restoring cams to turn through half a revolution.

Paper Feed Mechanism

The tape feed shaft has fixed to it the tape feed wheel, a feed ratchet, a back-space ratchet and retention wheel, and the whole is mounted on the punch block assembly. During operation, the feed ratchet is lowered past the end of the feed pawl, mounted on the anvil bracket, and engages the next tooth. When the punch block moves upwards the tape feed shaft is turned, and the tape advances by $\frac{1}{10}$in ready for the next character to be punched.

If an error is made in punching a character, it may be corrected by operating the back-space key and pressing the letter-shift key. This punches a teleprinter non-typing character, after which the correct character may be punched. When being received on a teleprinter the error will be undetectable.

Dismantling and Assembling Instructions

1. Keyboard

1.1 Remove the plug of the end-of-line indicator lamp circuit (if fitted).

1.2 Remove the two large screws which secure the keyboard to the main base, and withdraw the keyboard.

2. Perforator operating unit (**Figs 3.22** and **3.23**)

2.1 If a counter unit is fitted, slacken the clamp screw of collar H, **Fig 3.22**, and withdraw the collar. Remove the counter unit resetting link from the spindle of the collar, and replace the collar.

2.2 Lift the locking frame L, **Fig 3.23**, up as far as it will go, and remove the three operating unit fixing screws which secure the unit to the keyboard back plate.

NOTE: When removing the left-hand screw, care should be taken to insert the screwdriver through the hole in the key bar guide rack in such a manner that the key bar springs are not damaged.

2.3 Lift the unit off the keyboard, carefully disengaging the linkages between it and the combination unit. (When reassembling, ensure that the selecting levers AO, and the trip lever AM, are correctly engaged with their appropriate linkages to the combination unit and the perforator link unit.)

3. Counter unit (if fitted) (**Figs 3.22** and **3.23**)

3.1 Disengage the wire resetting link from the pivot of collar H, **Fig 3.22**, after removing H. Remove the three fixing nuts and washers securing the counter unit to the perforator operating unit back plate, and lift off the counter unit.

N.B. Do not disturb the counter unit locating plate B, **Fig 3.23**, whether or not the fixing screw is painted red.

4. Perforator unit (**Figs 3.24**, **3.25** and **3.26**)

4.1 Remove the cuttings box and its bracket, together

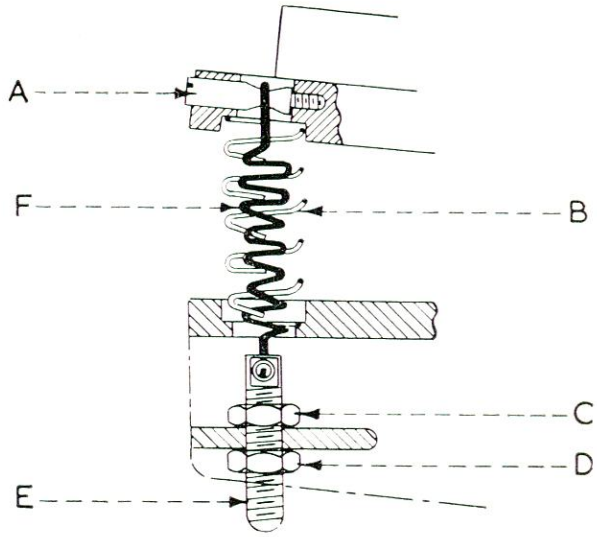


Fig 3.24. Perforator unit.

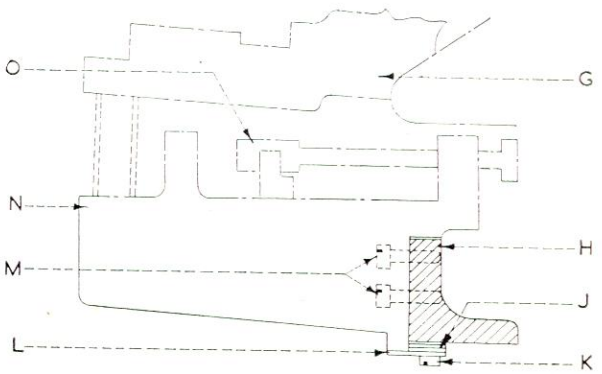


Fig 3.25. Anvil bracket.

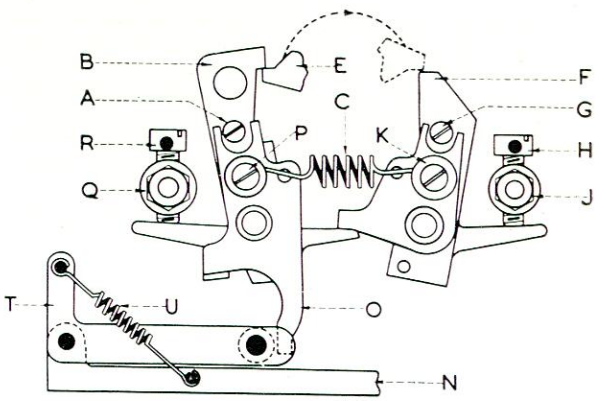


Fig 3.26. Retention pawls.

with the punch head guard plate which covers the damping springs B and F, **Fig 3.24**.

4.2 Take up the tension of the inner damping spring F by means of a spring hook engaged with the top of the spring, and remove the anchor screw A. Relax the tension and remove the hook.

4.3 Compress the outer damping spring by pulling it downwards with its spring hook, and remove it from the inner spring.

4.4 Remove the three punch block unit fixing screws from the rear of the keyboard back plate. Press the punch withdrawing bracket V, **Fig 3.27**, to the left, out of engagement with the recesses in the punches, hold the feed pawl E out of engagement with the feed ratchet, and lift off the complete punch block unit.

(When reassembling:

(*a*) The left-hand fixing screw of the keyboard should be placed in its hole in the keyboard casting before the punch block unit is reassembled to the keyboard, and wedged in position, eg with a matchstick. If this is not done, difficulty may be experienced in inserting the screw into its hole after the punch block unit is reassembled.

(*b*) Turn each punch so that the recessed portion faces the punch withdrawing bracket. Engage the bracket in the recesses before securing the punch block unit to the keyboard.)

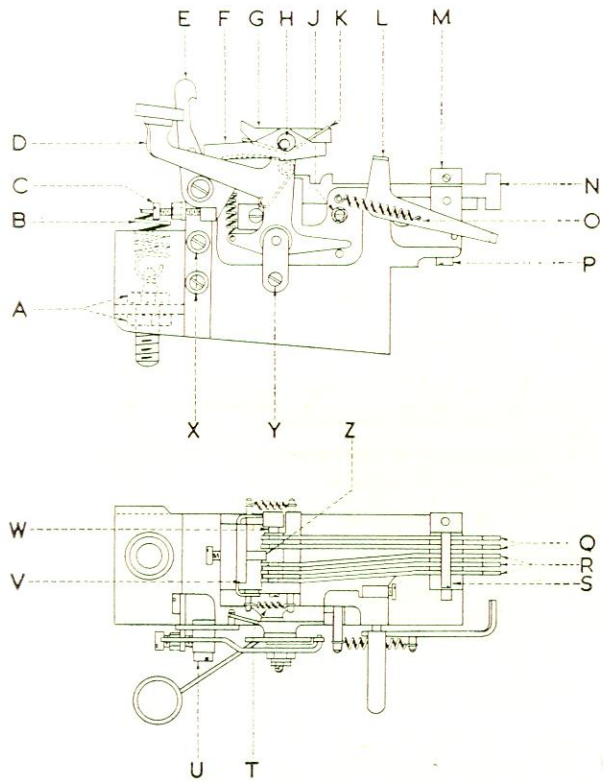


Fig 3.27 Anvil bracket

4.5 Remove the two fixing screws M, **Fig 3.25**, and take off the anvil bracket N from the keyboard.

(When reassembling, ensure that the right-hand ends of the selector bars O are engaged correctly with the punch block operating levers on the combination unit, and that the throwout link T, **Fig 3.26**, is not wrongly placed under detent extension O).

5. Perforator link unit

5.1 Remove the two sets of screws and washers securing the perforator link unit and lift it from the keyboard.

6. Combination unit

6.1 Turn the keyboard over and remove the four fixing screws (two at each end) from the combination unit. Lift the anvil bracket end of the unit clear of the casting and carefully withdraw the unit.

N.B. Note between which two key bars the wire link to the counter unit is passed.

7. Motor governor unit (governed motors only)

7.1 Slacken the screw which clamps the governor unit to the motor shaft, and withdraw the governor unit.

8. Motors and gears

8.1 Turn the machine over, and remove the motor connection wires from their anchorage on the connection block, taking care to note the terminals used for each coloured wire.

8.2 Remove the clip securing the motor cable to the main base.

8.3 Hold the motor in place, and remove the two large screws which secure it to the main base. Remove the motor, and withdraw its cable.

N.B. The four (headless) screws and nuts which position the motor on the main base are usually painted red. They should not be disturbed, whether painted or plain.

8.4 Remove the four screws securing the intermediate driving shaft bearing blocks to the main base, and remove blocks, shaft and gears, taking care not to lose any shims which may be present.

8.5 If it be desired to dismantle the shaft and gears from the bearing blocks, the method of procedure is self-evident.

To Dismantle Individual Units

9. Keyboard (**Figs 3.28** and **3.29**)

9.1 Withdraw the two screws, J, **Fig 3.29**, and remove the keyboard mask G and key bar guide rack.

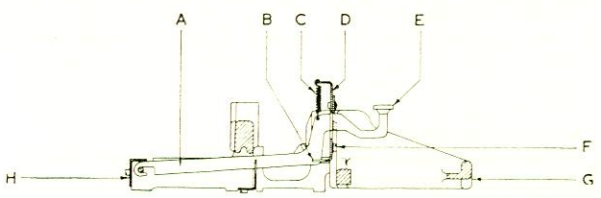


Fig 3.28 Keyboard.

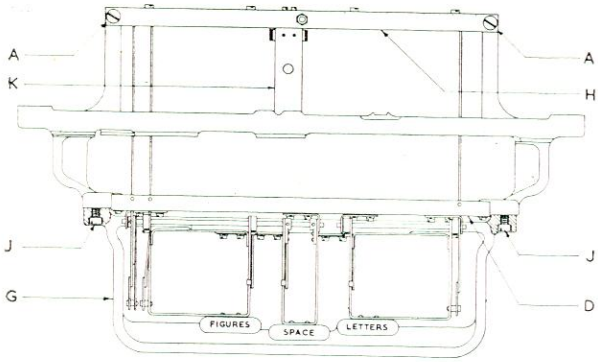


Fig 3.29. Keyboard.

9.2 Remove the two sets of screws and washers F, **Fig 3.28**, and lift off the stop plate B, complete with "Figures", "Letters" and "Space" key bars, if fitted.

9.3 Remove the two screws A, **Fig 3.29**, and lift off the keep plate H.

9.4 Disengage the springs C, **Fig 3.28**, from the key bars E, and remove the key bars.

N.B. If more than one or two key bars are removed, it is advisable to make a sketch plan of the keyboard layout, ie a list should be made of all the slot numbers in the front rack D with their corresponding key bars.
(When reassembling check that the springs on the "Figures", "Letters" and "Space" key bars have a greater number of coils than the other springs. Ensure that the tops of the springs are anchored in the correct holes, and that the key bars are in their correct slots.)

9.5 Further dismantling should not, normally, be necessary, but if it is desirable, the method of procedure is obvious.

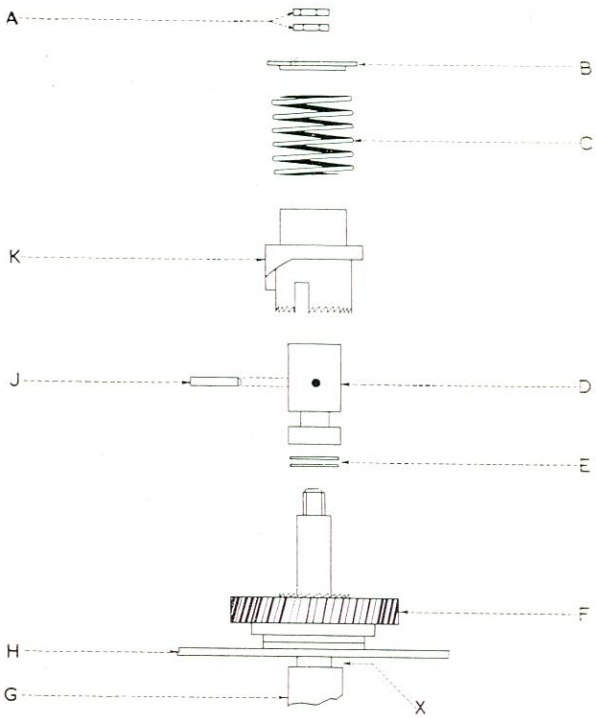


Fig 3.30. Part of perforator operating unit

10. Perforator operating unit (**Figs 3.30** and **3.31**)

10.1 Remove the two sets of screws and washers AG, **Fig 3.31**, which secure the driving shaft at the rear of the unit. Remove the driving shaft AH, complete with driving gear O and two bearing blocks AF.

10.2 Remove the three sets of nuts and washers AB securing the front plate U, and remove spring AK from its anchor pin.
(When reassembling, position the retention lever C so that it is approximately central with the retention cam, and there is a small clearance between its shouldered bush and the front plate. Move the collar Z against the retention lever C and clamp it in position.)

10.3 Remove the front plate U. Remove the lubricator fixing nut and washer S, and remove the lubricator T, together with its spring V.

10.4 Unhook the detent spring from its anchor pin. Remove the two sets of bolts and washers which secure the detent N and remove the detent. Remove the detent mounting block M, taking care not to lose the shims from between the block and the back plate.
(When reassembling, place the detent block M so that the end which is farthest away from a screw hole is towards the back plate.)
If there is any doubt as to the number of shims which

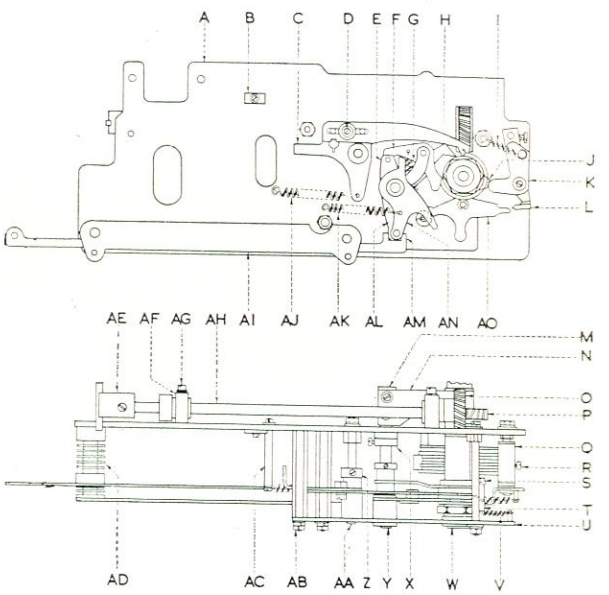


Fig 3.31. Perforator operating unit.

should be placed between the detent block and the back plate, carry out the following procedure:

(*a*) Assemble the detent block M and fixing screws without any shims.

(*b*) If collar X is secured by its screw, this should be slackened.

(*c*) Position the shaft so that the latch F is centrally opposite to the detent reset cam.

(*d*) Move the collar X against the bush in the back plate, and secure it with its screw.

(*e*) Pull the detent shaft away from the back plate and measure the gap between collar X and the bush.

(*f*) Remove the detent mounting block, and insert sufficient 5mil shims between the detent block and the back plate to reduce the gap just measured to 5mil or less.

(*g*) Reassemble the detent block and detent, complete with shims.

10.5 Remove the locknuts A, **Fig 3.30**, the retaining plate B and the clutch spring C.

N.B. If difficulty is found in holding the cam shaft assembly G steady in order to remove the lock nuts A, a spanner may be fitted to the flats of the collar (not shown) which abuts the first cam from the backplate H. On reassembly, the same method of holding the shaft may be used.

10.6 Remove the ratchet K.

10.7 Push out pin J and remove the clutch dog D, taking care not to lose the shims E, and remove the gear wheel F from the cam shaft G.

(When reassembling, care should be taken to replace the clutch dog D and ratchet F so that they are in correct relationship to the camshaft spindle before fitting the pin J. This may be achieved by turning the cam shaft until the retention lever is resting in its cam fall, and turning the clutch dog and ratchet until one camming out face of the clutch is uppermost. If there is any doubt as to the number of shims which are needed between gear F and dog D, the following procedure should be carried out:

(*a*) Reassemble the clutch as described above, but without any shims between dog and gear.

(*b*) When the pin J is in position, pull the camshaft forward away from back plate H so that there is a gap between the shaft and its oil-impregnated bush in the back plate at point "x".

(*c*) Measure the gap at "x" and insert sufficient 5mil shims between the gear and dog to bring the gap down to 5mil or less.)

10.8 Detach the spring I, **Fig 3.31**, of locking frame L from its anchor pin. Slacken the screw R and withdraw the locking frame L, locking lever K, and collar Q from their common pivot.

(When reassembling, care should be taken to position the locking frame on its pivot so that the toe of the locking lever is central with the keyboard locking cam J.)

10.9 Unhook the spring AJ from its anchor pin, and remove the retention lever C from its pivot, complete with spring. Remove collar Z.

(When reassembling, the screw in the collar should be left loose.)

10.10 Remove the detent control shaft Y and associated parts, ie detent operating lever AN, latch carrier E, latch F and perforator release lever AL.

(When reassembling, engage the perforator release lever AL in the claw of the release bar AM. If collar X has been disturbed, it should be positioned so that latch F is centrally opposite to the detent reset cam H.)

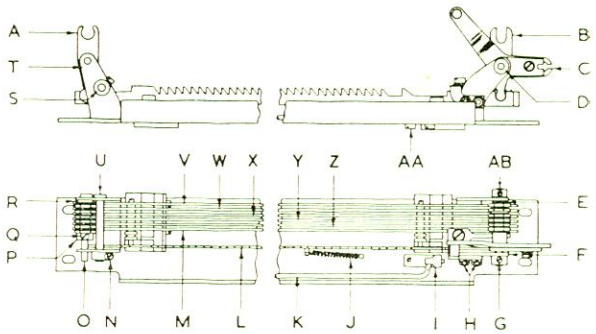


Fig 3.32. Combination unit.

10.11 Remove the cam shaft W, complete with cams.

10.12 Remove the clip which retains selector levers AO on their common pivot.

(When reassembling the clip, ensure that the selector levers are free on their pivot, but have the minimum of end play.)

10.13 Remove the selecting levers AO, taking care not to lose the intervening spacers, which are liable to spring off the pivot.

(When reassembling, one spacer should be placed between each pair of selecting levers, and also between the first selecting lever and the bush in the back plate.)

10.14 Remove the retaining pillar AC and lift off the release bar AM from the guide racks AD.

10.15 Procedure for further dismantling of the perforator operating unit is self-evident, but it should not, normally, be necessary to continue beyond this stage. The screw of the counter unit locating plate B is usually painted red, but it should not be disturbed, whether painted or plain.

11. Counter unit (**Fig 3.22**)

11.1 Remove the two screws securing the contact pileup F, **Fig 3.22**, and lift off the pileup, complete with flex lead and plug (not shown).

11.2 Release spring J from its anchor pin.

11.3 Loosen the screw in the retaining collar H and remove the spring resetting lever D.

11.4 Remove two collars, one on the pivot of contact operating lever K and the other on the pivot of the retention pawl B. Remove the washer and the lever K.

(When reassembling, replace the contact operating lever K so that the pivot of the retention pawl protrudes between the forked ends.)

11.5 Release the spring A from its anchor pin and remove the stop plate L.

(When reassembling, before replacing the stop plate L, rotate the ratchet wheel G in an anti-clockwise direction sufficiently for the stud on the wheel to clear the stop plate L.)

11.6 Release the long spring M attached to the ratchet wheel G. Remove the collar and ratchet wheel G from their common pivot.

11.7 Remove the collar and feed link E from their common pivot, after releasing the feed link spring.

11.8 Release the spring C from its anchor pin and withdraw the retention pawl B, taking care not to lose the distance collar on top of the pawl.

11.9 Release the damping buffer spring from its anchor pin at the rear of the unit. Slacken the clamping nut and withdraw the damping buffer screw. Remove the components of the damping buffer, ie spring, clamp plate, friction plates, damping buffer and second friction plate.

N.B. When the counter unit has been completely assembled, but before it has been replaced on the keyboard, adjustments as in Section C should be carried out.

12. Combination unit (**Fig 3.32**)

12.1 Remove the collar (or Anderton clip) which secures pivot G, **Fig 3.32**, in bracket F. Withdraw the pivot from the rear, removing from it successively:

(*a*) trip lever C
(*b*) spacing washer
(*c*) split ring (or collar)
(*d*) five connecting levers B, with four intervening split rings
(*e*) shims E.

(When reassembling, replace the pivot from the rear, thread on the above parts in reverse order, taking care that the shoulders of levers B face the front of the unit. When reassembled, all levers should move freely, but with a minimum of end play.)

12.2 Slacken screw Q and withdraw pivot O slowly, removing from it successively:

(*a*) collar P
(*b*) five connecting levers A, with four intervening split rings.

(When reassembling, insert pivot O through the hole in its support from the rear, threading on the parts listed above in reverse order, ensuring that the shoulders of the levers are towards the front of the unit. Check, after assembly, that the parts are free to move on their pivot, but have the minimum of end play.)

12.3 Slacken screw N and remove collar S. Withdraw the pin U.

12.4 Withdraw the five combination bars V, W, X, Y and Z. Lift the left-hand end of the locking bar M, and withdraw it. Release spring J from its anchor pin on the trip bar L and withdraw the bar.

(When reassembling, note that the five combination bars, and the locking bar, are numbered on their right-hand ends. They should be replaced in the following order:

No. 1 combination bar V (occupying rear slot)
No. 2 combination bar W (occupying rear slot)
No. 3 combination bar X (occupying rear slot)
No. 4 combination bar Y (occupying rear slot)
No. 5 combination bar Z (occupying rear slot)
Shift lock bar M, occupying sixth slot from rear,
Trip bar L, occupying the front slot.

Check that the combination bars move freely in their racks without any sticking, and that when the trip bar L is moved to the left and released it returns snappily under the action of spring J.)

12.5 Remove the trip bar spring J. Remove the two sets of screws and washers AA which secure the brackets for the End-of-Line Indicator trip rod K, if fitted. Remove the brackets, together with the rod.

12.6 Slacken the two sets of nuts and washers H which secure the locking bar jockey bracket and spring. Remove the bracket and spring.

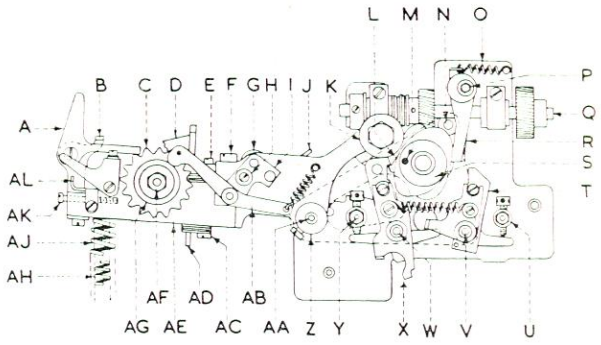


Fig 3.33. Punch block head.

12.7 The dismantling of the remainder of the unit is self-evident, but is not normally necessary.

(When reassembling, if the combination bar racks have been removed, care should be taken to locate them correctly against the back of the combination bar support plate.)

13. Punch block unit (**Figs 3.33** and **3.34**)

13.1 Slacken the two screws D, **Fig 3.34**, which secure the cuttings Chute A, and withdraw the chute. Remove the screws C and E and remove the punch block head.

NOTE: Instructions for dismantling the punch block head are given in Section 14.

13.2 Remove the four sets of nuts and washers which secure the front support plate, shown dotted in **Fig 3.33**, at points N, V, W and AA. Remove the plate, taking care not to lose any shims which may lie between the cam sleeves end face S and its bearing in the plate.

13.3 Remove the collars from pivots V and W. Turn the cam until roller K is clear of the left-hand detent X, and lift off both detents X and T from their pivots, together with their common spring. Remove the spring.

N.B. It should not be necessary to remove the two collars behind the detent (not shown) which position the detents on their respective pivots, but if they are moved they should be replaced so that the detents lie centrally disposed with respect to the cam pawl L.

13.4 Disengage the front spring O from its anchor pin and remove the nut and washers from pivot P. Remove the following parts from the pivot:

(*a*) front eccentric collar
(*b*) front retention pawl R
(*c*) washer
(*d*) rear retention pawl and its spring
(*e*) rear eccentric collar.

13.5 Lift the cam sleeve and cam shaft, together, from their rear bearing, taking care not to lose any shims which may be present. Press the cam pawl L backwards against its circular flat spring, and withdraw the sleeve S from the shaft.

13.6 Push out the pivot pin M from the side of the cam remote from the pawl, and remove the pawl and pawl spring.

(When reassembling, replace the pawl in such a way that the tail of the pawl spring engages in the nick on the upper surface of the pawl.)

13.7 Remove the metal guard plates (not shown) which cover the gear wheels of the intermediate shaft Q. Remove the screws and spring washers which secure the shaft bearing blocks to the unit back plate, and lift off the complete assembly of shaft, bearing blocks and gear wheels.

13.8 Remove the collar Z and lift off the complete punch block casting from pivot AA.

13.9 Remove the spring from the tail of the tape feed retention pawl AB, and remove the pawl.

13.10 Remove the clamping screw and washer H of the retention pawl adjustment plate 1, and the capstan head eccentric screw, and lift the plate from its pivot.

13.11 Knock out the pivot of the adjustment plate I, taking care not to damage its end face, from the side farthest away from the plate, and remove the flanged tape guide roller G, taking care not to lose the shims which lie between the flanges of the roller and the punch head casting.

(When reassembling, position the roller by means of the shims so that the tape is centrally disposed about the punches.)

13.12 Remove the screw which secures the tape guide J to the punch head casting, and remove the guide.

14. Punch block head (**Figs 3.33, 3.34, 3.35, 3.36** and **3.37**)

14.1 Remove the spring M, **Fig 3.34**, from the tape guide frame L, and the spring N from the guide frame latch K.

14.2 Remove the two screws G and J, **Fig 3.35**, which secure the support bracket N to the underside of the punch block head, and remove the bracket, complete with the eccentric assembly M and the latch A.

14.3 Remove the two screws which secure the tape guide frame L, **Fig 3.34** to the punch block casting. Remove the frame, taking care not to lose the two spacing washers which lie between the frame and the casting.

14.4 Remove the two screws J and remove the tape guide H. Remove the two screws which secure the stripper spring AL, **Fig 3.33**, to the punch block unit, and remove the spring.

14.5 Remove the two screws B, **Fig 3.36**, which secure the cover plate C of the punch block head assembly, and remove:

(*a*) coverplate C
(*b*) two die plates D
(*c*) tape guide plate A
(*d*) four die plates Q
(*e*) five message punches O and the feed hole punch.

14.6 Turn the punch block over and remove the two

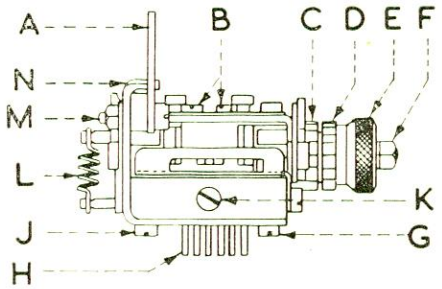


Fig 3.35. Punch block head.

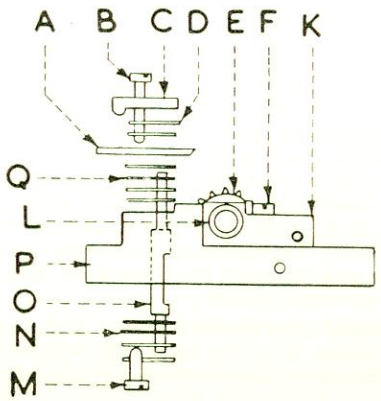


Fig 3.36. Punch block assembly

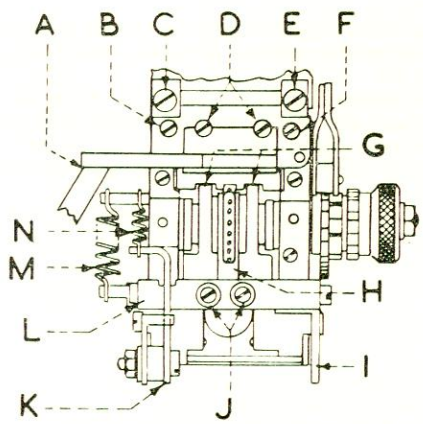


Fig 3.34. Part of punch block head.

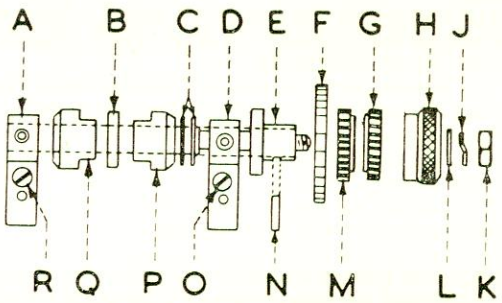


Fig 3.37. Part of punch block head.

screws M. Then remove the four bottom guide plates N. (When reassembling, replace the guide plates N, and die plates D and Q, so that their cut-away corners are towards the feed wheel knob. Ensure that the punches are free, after tightening screws B and M. It is advisable to tighten these screws alternately, each a little at a time.)

14.7 Remove the four screws O and R, **Fig 3.37**, which secure the feed wheel shaft bearing blocks A and D to the punch head casting, and lift off the complete feed wheel shaft assembly.

14.8 Remove the left-hand bearing block A from the shaft, taking care not to lose the shims, if fitted.

14.9 Remove nut K, spring washer J and washer L, knock out the rivet and remove the feed wheel knob H, the back space ratchet G, the feed ratchet M and the retention sprocket F.
(When reassembling, place the two ratchets G and M shoulder to shoulder, with ratchet G feeding clockwise and ratchet M anti-clockwise, as viewed from the feed wheel knob side.)

14.10 Knock out pin N, which secures the ratchet bush E to the feed wheel shaft. Remove the bush, followed by the right-hand bearing block D and shims C.
(When reassembling, replace the bearing blocks A and D so that when they are viewed from the feed wheel knob end of the shaft, their locating pins point in an anti-clockwise direction, and ensure that the feed wheel shaft rotates freely when the bearing blocks are screwed down.)

15. Anvil bracket (**Fig 3.27**)

15.1 Remove the fixing screw of the bracket which carries the feed pawl adjusting screw C, **Fig 3.27**, and remove the bracket. Remove the screws X, and remove the feed pawl E, together with its supporting bracket, disengaging the pawl return spring from the tail of the back space key D. Remove the pivot screw of the pawl, and separate pawl and bracket.

15.2 Remove the screw Y which secures the pivot bracket of the back space key D, and remove bracket, pivot and key. Remove the back space key assembly from its pivot, and dismantle the eccentric H, thus separating the key sections F and G.

N.B. Careful note should be taken of the arrangement of the springs K of the compliant members, and they should be similarly arranged when reassembling.

15.3 Remove the two shouldered screws which secure the punch withdrawing bracket V to the casting. Detach the two bracket springs (one shown at T) and remove the bracket.

15.4 Remove the threaded pins S and W, which retain the selector bars. Remove the three "bent" selectors R, and the two straight bars Q.

15.5 Remove the two screws which secure anvil Z, and remove the anvil. Remove the two screws securing the selector bars' guide rack to the anvil bracket casting, and remove the rack, taking care not to lose the shims from between rack and casting.

15.6 Remove the two nuts A, and the threaded spring adjuster, complete with tension spring B.

16. Motor unit (motors type KBB and KBE only) (**Fig 3.38**)

16.1 Slacken the screw securing the drip proof cover and remove the cover.

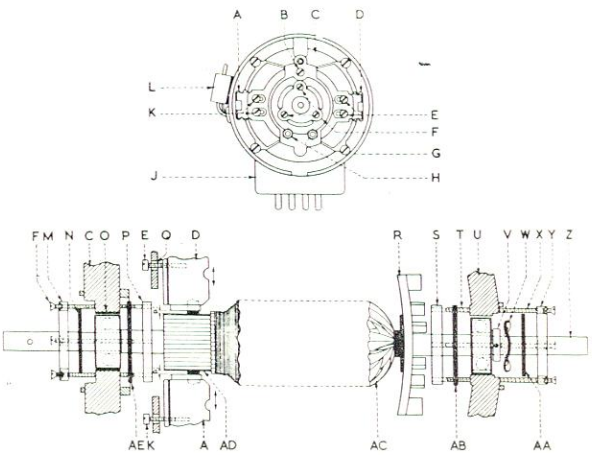


Fig 3.38. Motor unit.

16.2 Remove the brush box covers, followed by the brushes, noting the position of each brush in its box. Slacken the two screws securing each brush box and remove the boxes, leaving them suspended on their connection wires.

16.3 Remove the two screws which secure the end plate U, **Fig 3.38**, to the motor body.

16.4 Remove the three screws which secure the trefoil shaped clamp ring M to the inner clamp ring P. Remove ring M and gasket N.

16.5 Using a hide or wooden mallet, gently tap out the armature shaft from the commutator end, and remove the complete armature and end plate assembly.

16.6 Remove the three screws which secure the trefoil shaped clamp ring Y and remove the clamp ring, followed by gasket AA, special spring washer W and motor end plate U.

16.7 Release the screw of locking collar V and remove the collar. Using bearing extractors, remove each ball race, and the clamp rings P and S with their gaskets AE and AB.
(When reassembling the motor unit, replace the parts as follows:

(*a*) Place new fibre gaskets on their respective rings, taking care to register the screw holes in each gasket ring pair.

(*b*) Replace the clamp rings P and S, and their gaskets AE and AB, on the armature shaft. Replace the two ball races and the locking collar V, ensuring that the latter is pushed hard up against the race, and tighten the fixing screw.

(*c*) Obtain a piece of 6BA screwed rod, about 3in in length, and engage it for a few turns into one of the screw holes of clamp ring S.

(*d*) Smear a little grease in the housing of ball race T, and hold the armature shaft upright, commutator end downwards.

(*e*) Lower the motor end plate into position on the shaft, passing the 6BA rod through one of the clamping screw holes in the end plate U.

(*f*) Replace the special spring washer W on the ball race, and lower the trefoil shaped clamp ring, and

gasket, into position, passing the rod through a screw hole.

(*g*) By means of the rod, raise the inner clamp ring S into contact with the end plate U, and insert two screws to hold it in place. Remove the rod and insert the third screw. Tighten the three screws, each a little at a time, in turn.

(*h*) Engage the 6BA rod for a few turns into one of the screw holes of clamp ring P. Replace the armature into the body of the motor, passing the rod through one of the clamping screw holes in the commutator end plate C.

(*i*) Rotate the tongue on end plate U into register with the slot in the motor body and tap the shaft home. Press the end plate U firmly into contact with the motor body and secure with its two clamping screws, tightening each in turn.

(*j*) Replace the trefoil shaped clamp ring M, and gasket N, passing one screw hole over the 6BA rod. Secure M to ring P by the method given in (*g*) in the previous page. Ensure that the shaft rotates freely. If this is not so, tap the shaft with the mallet, at one end or the other, as may be found necessary.

(*k*) Reassemble the brush boxes to the rocker arm, adjusting their fixing screws E and K in their slots to give a clearance from the commutator of 10–15mil (0·25–0·38mm) at "a". Clamp the fixing screws before removing the feeler.

(*l*) Replace the brushes in the channels from which they were removed.

(*m*) Replace the drip cover, reassemble the motor on the teleprinter and replace the governor.

NOTE: If the brush rocker arm is removed, care should be taken to replace it so that the mark on the rocker lines up with the mark on the commutator end plate.)

ADJUSTMENTS

A. Perforator Operating Unit

1. Retention lever (**Fig 3.39**)

Check

1.1 With the keyboard off the main base, turn the cam shaft by hand until retention lever B, **Fig 3.39**, drops into a recess of cam C. Turn the clutch ratchet J anti-clockwise (as viewed from the rear of the keyboard) as far as it will go, ie until the pin of the detent G is located against the straight part of the camming out face of the ratchet, and hold it there.

1.2 With the clutch ratchet held in this position, check that there is a gap of 70–80mil (1·78–2·03mm) ie dimension "a" (inset) between the end of the retention lever B and the vertical face of the recess in cam C.

Action

1.3 If this is not so, holding the clutch ratchet firmly against the detent pin, slacken screw A and adjust retention lever B, by means of the screwdriver slot, until dimension "A" is obtained. Tighten screw A.

Check

1.4 Repeat Checks 1.1 and 1.2 for the other recess of cam C.

Action

1.5 If Check 1.4 is not satisfactory, readjust the position of the retention lever until Checks 1.2 and 1.4 are both simultaneously satisfied.

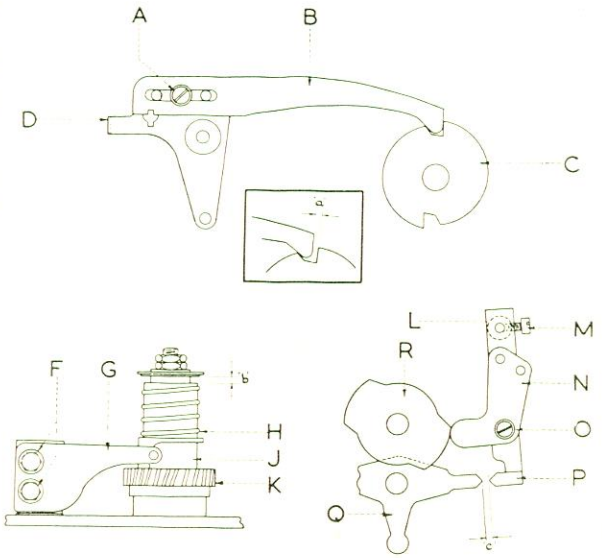


Fig 3.39. Trip detent.

2. Trip detent (**Fig 3.39**)

Check

2.1 With the keyboard in the rest position, check that there is a clearance of 10–12mil (0·25–0·30mm) between the teeth of the clutch ratchets.

N.B. On some keyboards it may not be possible to measure this dimension directly, with accuracy, because the teeth of the gear ratchet are recessed below the gear. If this is the case, the following indirect method of measuring the dimension may be used:

(*a*) Pull forward spring H, **Fig 3.39**, to expose gap "b". Measure and note the size of this gap.

(*b*) Lift detent G, and rotate the clutch ratchet through a quarter of a revolution.

(*c*) Pull forward spring H again and insert various thicknesses of feeler gauge into gap "b" until, with the clutch ratchet pressed back to grip the gauge, the tips of the ratchet teeth are just touching. This can be tested by touch, by rotating the gear wheel K. Note the value of gap "b".

(*d*) The difference between the two values for gap "b" should be 10–12mil (0·25–0·30mm).

Action

2.2 If the clearance between the clutch ratchet teeth was measured by the direct method as given in Check 2.1 but was found to be incorrect, then slacken the detent fixing screws F and adjust detent G on its pivot to obtain the required dimension. Tighten screws F.

2.3 If the clearance between the clutch ratchet teeth was measured by the indirect method, as given in Check 2.1, and was found to be incorrect, then turn the shaft to the rest position and slacken screws F.

2.4 Set the feeler gauge to the value of gap "b" as found

in paragraph 2.1(*c*) minus 11mil (0·28mm), and insert it in gap "b".

2.5 Pull the ratchet back to grip the gauge, move the detent G outwards until it is arrested by the camming out face of the ratchet, and tighten screws F.

3. Locking frame (**Fig 3.39**)

Check

3.1 With the unit in the rest position, ie, with retention lever B, **Fig 3.39**, located in a recess of cam C, check that cam lever N is centrally aligned with the cam R, looking from the right-hand end of the keyboard unit.

Action

3.2 If this is not so, slacken screw M and adjust collar L until the correct condition is obtained. Tighten screw M.

Check

3.3 Check that, with the unit still in the rest position, there is a clearance of 5–15mil (0·13–0·38mm) ie dimension "c" as judged by eye, between the knife edges of the selectors Q and the locking frame P when they are in line.

Action

3.4 If this is not so, slacken locking screw O and set the correct gap by positioning cam lever N. Tighten the locking nut of screw O.

B. Combination Unit

4. Locking bar jockey spring (**Fig 3.40**)

Check

4.1 With the unit off the keyboard, check that the locking bar A, **Fig 3.40**, moves snappily from one shift to the other when a force of 5½–7oz (156–196g) is applied to it. The forces required to move the bar in either direction should be equal to within ½oz (14g).

Action

4.2 If adjustment is necessary, slacken screw B and position spring C to give the correct conditions.

5. Trip bar stop and trip lever (**Fig 3.41**)

Check

5.1 With the unit on the keyboard, depress each key in turn and note which one gives the least lift to the trip detent L (inset), **Fig 3.41**.

5.2 With this key depressed, there should be a clearance of approximately $\frac{1}{32}$in (0·8mm) between the pin of detent L and the rim of the clutch ratchet K, ie dimension "g".

5.3 With the machine in the rest position, check that there is a clearance of $\frac{1}{32}$in (0·8mm) between the detent release latch F and the detent operating lever E, ie dimention "f".

Action

5.4 If either of the above conditions is not obtained, adjust as follows:

5.5 Slacken the locknut of stop screw J and adjust the screw until dimension "f" is approximately $\frac{1}{16}$in (1·6mm) Clamp screw J lightly with its locknut.

5.6 Holding down the key which gives the least lift to the trip detent (as described above in Check 5.1) slacken screw G and, by means of the screwdriver slot H, set up a clearance of $\frac{1}{32}$in (0·8mm) between the clutch ratchet K

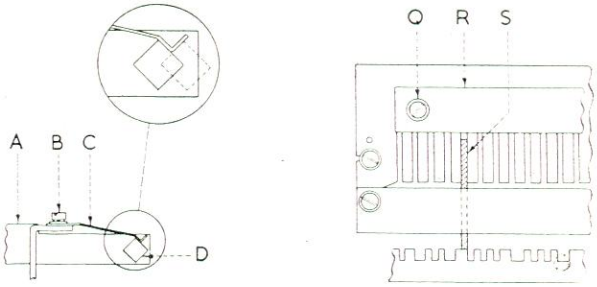


Fig 3.40. Locking bar jockey spring.

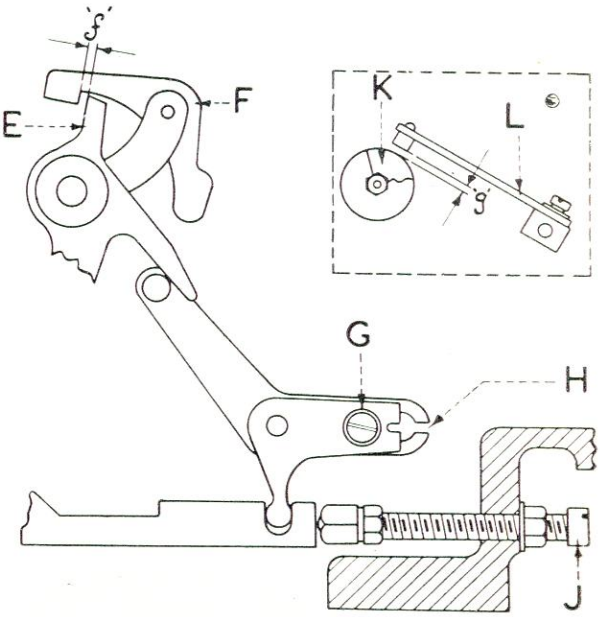


Fig 3.41. Trip bar stop and trip lever.

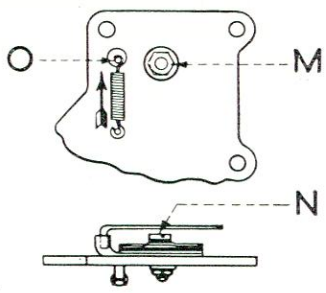


Fig 3.42. Damping buffer.

and the pin of the detent L, ie dimension "g" (inset). Tighten screw G.

5.7 With the machine in the rest position, slacken the locknut of stop screw J and adjust the screw until the clearance between the detent release latch F and the detent operating lever is $\frac{1}{32}$in (0·8mm), ie dimension "i". Clamp screw J with its locknut.

C. Counter Unit

6. Damping buffer (**Fig 3.42**)

Check

6.1 Check that a force of 11–13oz (0·31–0·37kg) applied against pin O, **Fig 3.42**, in the direction of the arrow, will just move the damping buffer.

Action

6.2 If it does not do so, slacken nut M and hold it with a 6BA spanner. Adjust screw N until Check 6.1 is satisfied, and tighten nut M.

7. Feed pawl (**Figs 3.43**, **3.44** and **3.45**)

N.B. Check 7.1 should be carried out only at major overhauls, when the unit is off the keyboard.

Check

7.1 With the retention pawl L, **Fig 3.44**, engaging one of the teeth of ratchet wheel J, check that there is a clearance of 8–12mil (0·20–0·31mm) ie dimension "n", between the top edge of the feed pawl F and the engagement face of the fourth tooth past the one in engagement with the retention pawl L.

Action

7.2 If this is not so, slacken screw H, **Fig 3.43**, and position the feed pawl F, by means of the screwdriver adjustment G, to satisfy Check 7.1. Tighten screw H.

Check

7.3 Turn the ratchet wheel J, **Fig 3.45**, until the retention pawl L is resting on top of a tooth. In this position, the grub screw P should clear the retention pawl extension (tail) by 3–5mil (0·08–0·13mm) ie dimension "o".

Action

7.4 If this is not so, slacken the locknut of grub screw P and adjust the screw until Check 7.3 is satisfied. Tighten the locknut of screw P.

8. Contact blades (**Fig 3.22**)

Check

8.1 Feed the counter on until the contacts F, **Fig 3.22**, close, and check that there is a gap of 5mil (0·13mm) between the ear of the left-hand contact blade and its stop.

Action

8.2 If this is not so, "set" the contact stop to satisfy the required condition.

Check

8.3 Trip the counter and check the gap between the contacts. This should be 15mil (0·38mm).

Action

8.4 If this is not so, "set" the right-hand contact blade to obtain the required dimension.

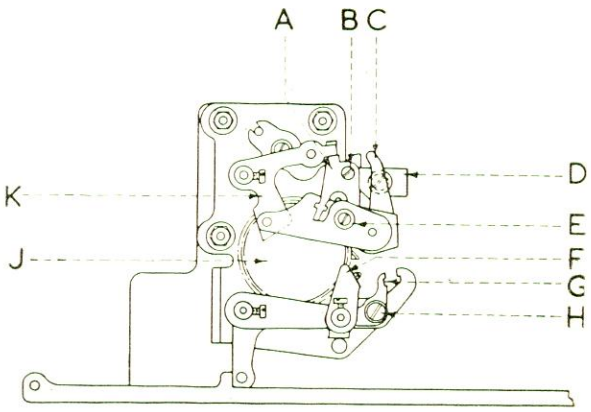


Fig 3.43 Retention pawl extension and trip lever.

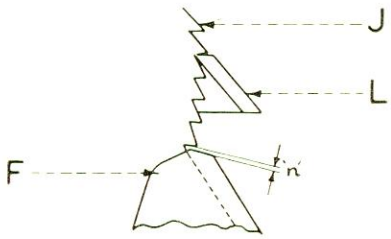


Fig 3.44. Retention pawl and ratchet wheel adjustment.

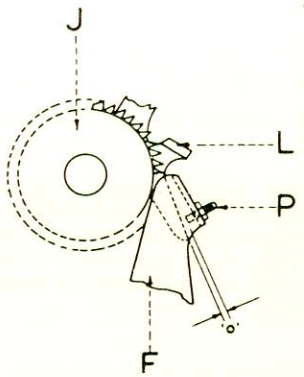


Fig 3.45. Retention pawl adjustment.

9. Retention pawl extension (**Fig 3.43**)

Check

9.1 Check that, with the counter unit in the rest position, the latching face of the retention pawl extension A, **Fig 3.43** is flush to 5mil (0·13mm) underflush with the right-hand face of the stop plate extension K, and ensure that the stop plate extension does not drop when the counter unit is stepped round by hand.

Action

9.2 If check 9.1 is not satisfied, slacken screw B and move the retention pawl extension A until the correct condition is set up. Tighten screw B.

10. Trip lever (**Fig 3.43**)

Check

10.1 Feed on the counter unit a few teeth by hand. Slowly depress the carriage return key, and check that the unit trips at the same moment as the clutch of the perforator operating unit.

Action

10.2 If this is not so, slacken screw E, **Fig 3.43**, and, by means of the screwdriver adjustment, position the trip lever until the required condition is obtained. Tighten screw E.

D. Keybar Stop Plate

11. Keybar travel (**Fig 3.40**)

Check

11.1 Depress the "figures" key. Depress any key in the "letters" case on the left-hand side of the keyboard, and check that the clearance between the upper stop plate R, **Fig 3.40**, and the depressed key bar S is between 30–40mil (0·75–1·0mm).

11.2 Depress the "letters" key, and repeat the above Check with a key in the "figures" case on the right-hand side of the keyboard.

Action

11.3 If either of the above conditions is incorrect, slacken screws Q, and position the stop plate R until the correct clearance is obtained at both ends of the keyboard.

N.B. If adjustment is carried out, ensure that the combinations bars move freely, without touching the key bars at any point.

E. Perforator Unit

12. Punch block vertical play and clutch detents (**Figs 3.33, 3.46** and **3.47**)

Check

12.1 Depress any key, and turn the motor by hand. Press down on the left-hand end of the punch block unit, and check the clearance between cam follower roller K, **Fig 3.33**, and cam L throughout its half revolution. Depress the key again, and repeat the check for the second half revolution.

Action

12.2 If either of the above conditions is not satisfied, turn the cam L to the tightest point, ie to where the cam follower roller K is either binding against or is closest to cam L. Slacken the clamp screw which secures the eccentric pivot of the roller, and adjust the pivot until the estimated clearance between the roller and the cam is 1mil (0·03mm). Tighten the clamp screw.

Check

12.3 With the pawl E, **Fig 3.46**, resting, as shown, against the vertical face of right-hand detent F, check that there is a clearance "a" between screw H and the tail of detent F. This should be 22–28mil (0·56–0·71mm).

Action

12.4 If this is not so, slacken nut J, and adjust screw H to obtain the required clearance. Tighten nut J.

Check

12.5 Repeat Check 12.3, using the left-hand detent B, **Fig 3.47**, and screw R.

Action

12.6 If Check 12.5 is unsatisfactory, slacken clamp nut Q, and adjust screw R to obtain the required clearance at "a".

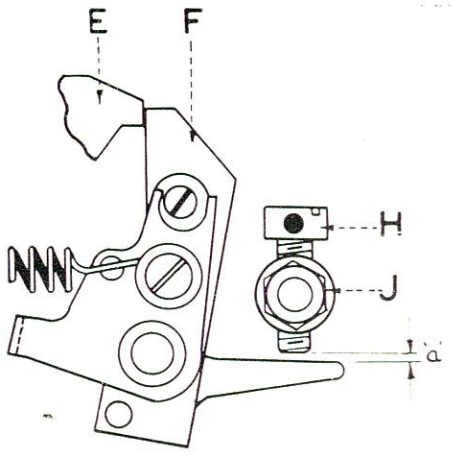


Fig 3.46. Clutch detent adjustment.

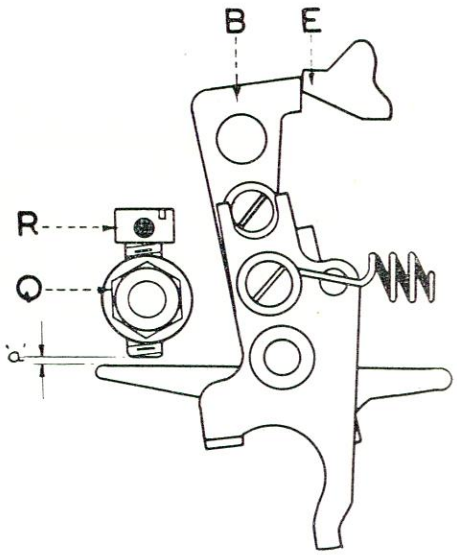


Fig 3.47. Clutch detent.

13. Retention pawls (**Figs 3.26** and **3.48**)

Check

13.1 Turn the cam shaft by hand until the pawl E, **Fig 3.26**, engages with the left-hand detent B, and the tail of the pawl is pressed firmly against the cam. Check that the clearance "b", **Fig 3.48**, between the tail of the rear retention pawl M and the cam face is 2–4mil (0·05–0·10mm).

13.2 Turn the cam pawl E, **Fig 3.26**, into engagement with the right-hand detent F, and repeat Check 13.1 for the front retention pawl M, **Fig 3.48**.

Action

13.3 If either of the above Checks is not satisfied, slacken nut L, which clamps the two eccentrics, and adjust the eccentrics to satisfy the required conditions, dealing with the rear eccentric first. Clamp nut L.

14. Trip adjusting arm (**Fig 3.49**)

Check

14.1 With the cam pawl E, **Fig 3.49**, clear of both detents B and F, hold the right-hand extension of detent F against screw H, and the right-hand extension of detent B against the bent foot on the adjustable plate on detent F. Check that the clearance "c" between screw R and the left-hand extension of detent B is 2–7mil (0·05–0·18mm).

Action

14.2 If this is not so, release screw K and adjust eccentric G to obtain the required condition. Tighten screw K.

15. Location of punch block unit (**Figs 3.50** and **3.51**)

Check

15.1 With the keyboard off the machine, depress the "letters" key and rotate the cam shaft by hand until the punch block head is fully down. Check that the punches H, **Fig 3.51**, are fully seated down on the selector anvils, with the sides of the punches flush with the vertical ends of the anvils.

N.B. The punch/anvil engagement may be easily viewed from the rear of the unit.

Action

15.2 If this is not so, remove the cuttings box, slacken screw K and rotate eccentric J away from the punch block unit backplate. Release the unit fixing screws.

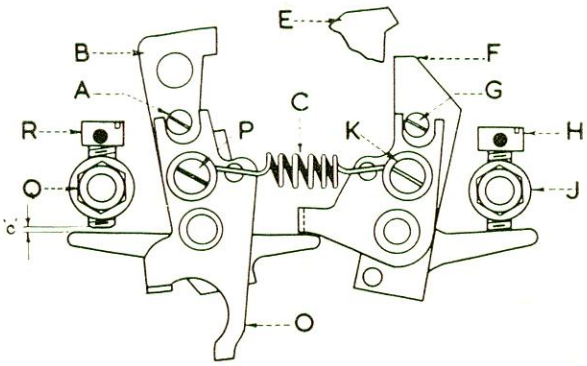


Fig 3.49. Trip adjusting arm, detent adjustment.

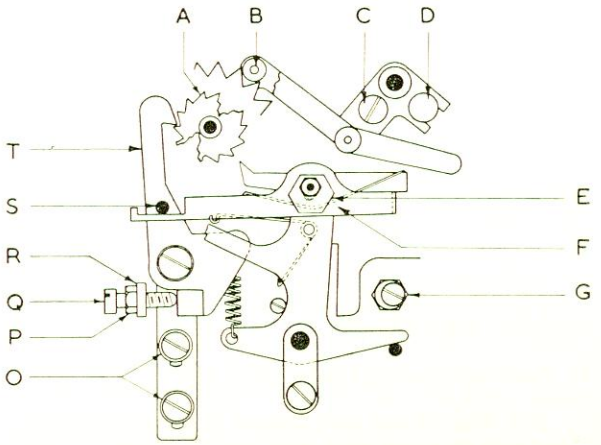


Fig 3.50. Tape feed latch.

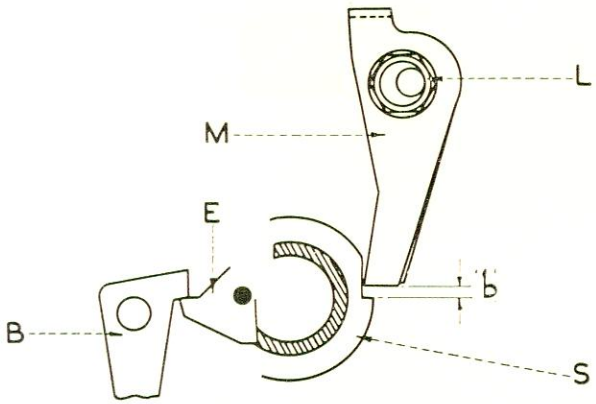


Fig 3.48. Retention pawls.

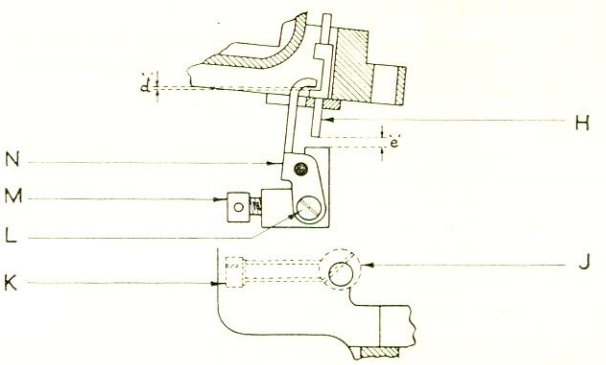


Fig 3.51. Punch withdrawing bracket.

15.3 Move the punch block unit until Check 15.1 is satisfied, and clamp into position with its fixing screws.

15.4 Rotate eccentric J into contact with the unit back plate and clamp it there with screw K. Replace the cuttings box.

16. Anvil bracket height—preliminary adjustment (**Figs 3.25** and **3.51**)

Check

16.1 With the selector anvils in the "mark" position, (ie fully to the left, under the punches) and the punch block fully raised, check that there is a clearance of 26–36mil (0·66–0·91mm) between the lower ends of the punches and the tops of the anvils, ie dimension "e", **Fig 3.51**.

N.B. If the punches have been re-ground, this dimension should be reduced by the amount by which the punches have been shortened.

Action

16.2 If Check 16.1 is not satisfactory, slacken screws M, **Fig 3.25**, remove the two screws K, and plate L, and add the correct number of shims at J to give the required dimension. Replace plate L, and clamp it with screws K.

16.3 With the anvil bracket seated down on plate L, tighten screws M.

17. Trip bar (**Fig 3.26**)

Check

17.1 Depress any key, and rotate the perforator operating unit cam shaft by hand. Check that detents B and F, **Fig 3.26**, are moved just clear of pawl E in both its positions.

Action

17.2 If this is not so, slacken clamp screw P and adjust trip arm O, by means of eccentric A, until Check 17.1 is satisfied. Tighten screw P.

18. Punch withdrawing bracket (**Fig 3.51**)

Check

18.1 With the cam pawl arrested by one of the detents, and with the punch block head held up, by hand, as high as it will go (to take up any vertical play), check that the punches can be moved upwards by an estimated 2–8mil (0·05–0·20mm) before they are arrested by the punch withdrawing bracket.

N.B. This check may best be made by means of a pair of tweezers, inserted through the "window" of the withdrawing bracket from the left-hand end of the unit.

Action

18.2 If Check 18.1 is not satisfied, release clamp screw M, **Fig 3.51**, hold the punch head up as high as it will go, and turn eccentric L slowly clockwise until the punches are pulled down against the bottom guide plate by the withdrawing bracket N.

N.B. Care should be taken not to force the punches down against the guide plate when the eccentric is turned.

18.3 Hold the punch head fully up, and measure the clearance at "e". Note this amount.

18.4 Turn the eccentric L anti-clockwise until an extra 2–8mil (0·05–0·20mm) can be inserted at "e". Clamp eccentric L with screw M.

18.5 Repeat Check 18.1.

19. Tape feed (**Fig 3.50**)

Check

19.1 With the cam pawl arrested by one of the detents and with the punch block head in the rest position, check that the feeding face of feed pawl T, **Fig 3.50**, nearly touches the bottom of a tooth of feed ratchet A. It should be just possible to move the pawl away from the ratchet without fouling the last tooth fed.

Action

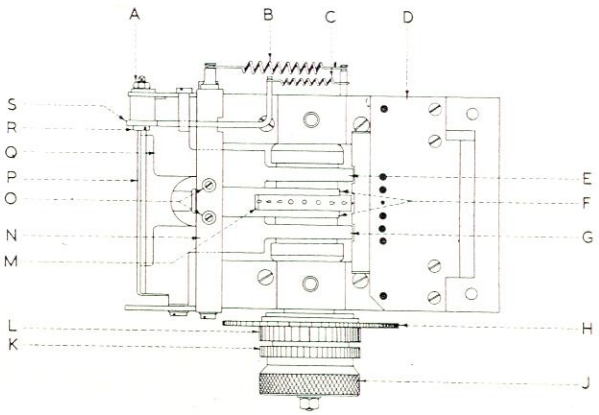
19.2 If this is not so, release clamp screws O and position the feed pawl assembly to satisfy Check 19.1. Tighten screws O.

Check

19.3 Release the cam detent and turn the perforator cam shaft by hand until the punch block head is fully down. Check that feed pawl T falls into the next tooth to be fed sufficiently to feed the ratchet on one tooth as the punch block head is raised up again.

Action

19.4 If this is not so, slacken nut P and adjust screw Q to obtain the required condition. Tighten nut P.



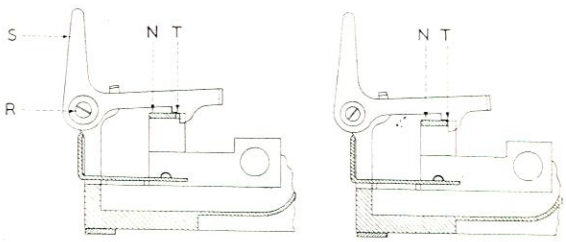


Fig 3.52. Tape feed latch.

20. Back space key (**Fig 3.50**)

Check

20.1 Depress the back space key and check that the compliant pawl of the assembly engages with the first tooth to the right of the vertical centre line of ratchet A, **Fig 3.50**, and feeds the ratchet back one tooth.

Action

20.2 If this is not so, slacken the nut clamping eccentric E, and turn the eccentric to adjust the height of the back space pawl so that when the key is depressed the pawl engages with the correct tooth of the ratchet. Tighten the clamp nut of eccentric E.

20.3 Slacken screw G and adjust the eccentric so that the backward feed is correct. Tighten screw G.

21. Tape feed latch (**Figs 3.50** and **3.52**)

Check

21.1 Check that the slot between the tines F, **Fig 3.52**, of the tape guide is centrally disposed about the teeth of the feed wheel M.

21.2 Insert a length of tape punched with feed holes, and check that the tips of the tines just touch the tape.

(*N.B.* This check may be performed as follows:

Raise the retention lever B, **Fig 3.50**, out of engagement with the sprocket wheel. Raise the tines F, **Fig 3.52**, and turn the knob J forward, noting the force required to do this. Lower the tines on to the tape, and turn the knob J again. There should be no discernible difference in the force required to turn the knob. Now check that there is no gap between the tips of the tines and the tape.)

Action

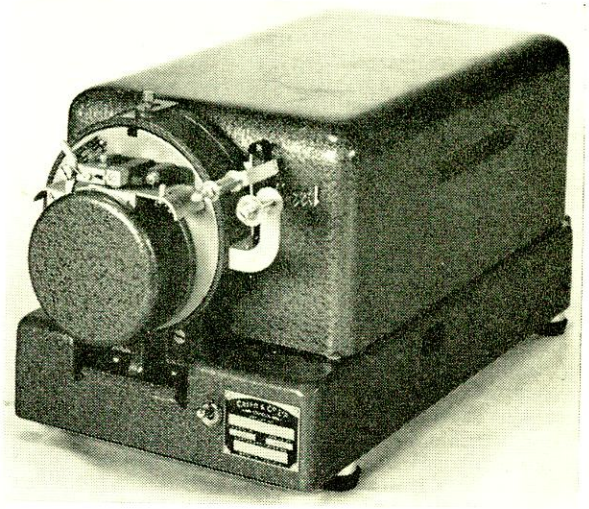
21.3 If either of these checks is not satisfied (or if the check detailed in Adjustment No. 40 is unsatisfactory), remove spring B, slacken nut A and turn eccentric R until latch S is disengaged from frame N, as shown in the left-hand sectional diagram of **Fig 3.52** at point T.

21.4 Slacken screws O and, pressing the tape lightly on to the rollers with guide F, slide the guide backwards and forwards until its curved underside is positioned concentrically with the rollers, ensuring that the slot in the guide is positioned centrally about the feed wheel teeth. Tighten screws O.

21.5 Replace spring B. Insert two thicknesses of tape punched with feed holes, and adjust eccentric R until, with the guide resting on the tape, the vertical face of latch S is just clear of frame N, at point T, as shown in the right-hand sectional diagram of **Fig 3.52**. Clamp the eccentric with nut A.

21.6 Remove one thickness of tape. Slacken screws O again and move the guide towards frame N until the tips of the tines F just touch the tape, ensuring that the slot is still centrally disposed about the feed wheel teeth. Tighten screws O.

21.7 Reassemble the keyboard to the main base.



A teleprinter automatic transmitter generally available to the amateur operator: the Creed 6S6. For internal view see p 3.3

CHAPTER 4

POWER SUPPLIES

THE power supplies designed to operate teleprinters and their associated equipment generally are similar to those intended for other electronic units, with the exceptions that they usually have to supply a large current at a high voltage such as would be the case with a motor supply, and often into a highly inductive load, such as clutch solenoids, polar relays, etc. Because of the need for higher power and for adequate suppression, such power units tend to be large and rather heavy, using good quality transformers and quite often copper oxide or selenium rectifiers because of their better overload characteristics.

RECTIFIER CIRCUITS

A rectifier in one of its several forms is necessary when ac is to be converted to dc. The rectifier functions by virtue of its property of unidirectional conduction, ie it passes current only when the applied voltage has the correct polarity to bias it to a low resistance condition. When the polarity of the input voltage is reversed the rectifier exhibits a very high resistance, approaching infinity in the case of a thermionic rectifier, and current cannot flow.

Figs 4.1 to **4.4** show three types of rectifier circuit which cover most of the applications in amateur equipment, together with curves indicating the shape of the current wave delivered by the rectifier in a resistive load. The output current is seen to be unidirectional but pulsating in character and may be shown to consist of a dc component plus an ac component. The ac component is composed of the fundamental and harmonics of the power supply frequency, the fundamental being predominant in the half-wave circuit and the second harmonic in the full-wave circuit. This ac component is termed ripple and may be removed or attenuated to any desired degree by the filter which follows the rectifier.

The half-wave circuit, **Fig 4.1**, is best suited to low-current applications. When used to supply current of the order of tens of milliamperes and higher, the half-wave circuit has disadvantages in that the ripple content is high, necessitating a large filter; in addition the dc load current flows through the secondary winding of the transformer feeding the rectifier, and can saturate the core giving rise to low transformer efficiency. The regulation or variation of output voltage with load current is also poor.

The full-wave circuit, **Fig 4.2**, also known more correctly as the bi-phase half-wave circuit, is the most commonly used rectifier circuit suitable for voltages up to about 1,500V and currents of the order of 1A. A centre tapped winding is used to supply the rectifiers and must provide twice the ac voltage applied to each rectifier. The load is connected between the centre tap of the transformer and the strapped output terminals of the rectifiers. Each rectifier conducts during the time when the voltage applied to its input is positive with respect to the centre tap, ie on alternate half-cycles, and contributes one half of the total load current. The dc component of the load current flows through each half of the transformer secondary in such a direction as to cancel the dc magnetization of the core, enabling a smaller and more efficient transformer to be used than is possible in a half-wave circuit providing the same output.

The bridge circuit, **Fig 4.3**, is preferred for higher voltage supplies since the peak inverse voltage across each rectifier is only half that of the bi-phase half-wave arrangement for

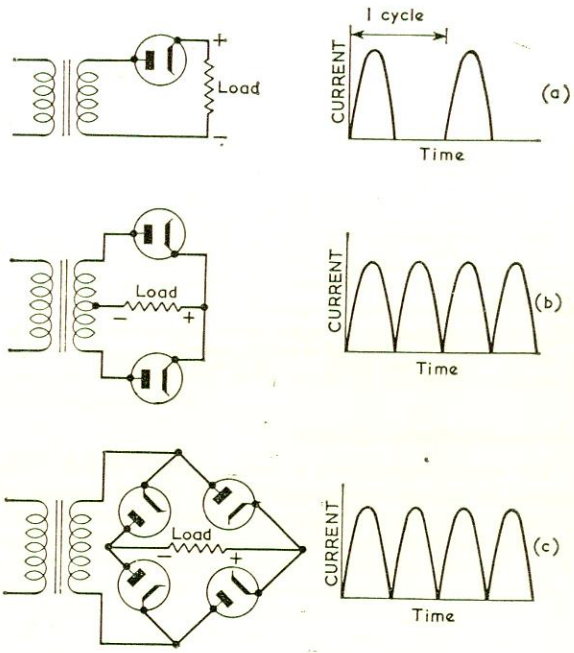


Fig 4.1. Half-wave rectifier circuit.

Fig 4.2. Full-wave or bi-phase half-wave rectifier circuit.

Fig 4.3. Bridge rectifier circuit.

Fig 4.4. Input waveform.

the same dc voltage output. The peak inverse voltage, referred to as a piv, is the voltage appearing across the rectifier diode in the non-conducting condition. During each half-cycle of the input voltage, the rectifiers in opposite arms of the bridge are conducting and supply half the total load current. The dc magnetization of the transformer core is effectively cancelled, as the dc component of the load current flows through the ht secondary winding in opposite directions during each half-cycle.

The advantage of the bridge is seen in the simplification and reduction in cost of the transformer. Relative to the bi-phase half-wave circuit, the rms current rating is reduced by about one-third, and the turns on the winding feeding the rectifiers by half. In practice this results in a smaller transformer used more efficiently.

A disadvantage of the bridge circuit when valve rectifiers are used is that three separate heater windings are necessary since only two of the four valves have cathodes at the same potential. A separate rectifier heater transformer is usually required due to the high voltage insulation required between windings and core.

Table 4.1 gives the operating conditions for each type of rectifier circuit.

TABLE 4.1

Single Phase Rectifiers

	Half-wave	Full-wave or biphase half-wave	Full-wave bridge
Circuit	Fig. 1 (a)	Fig. 1 (b)	Fig. 1 (c)
Number of rectifiers	1	2	4
Current per rectifier			
—mean	1·0 I_{dc}	0·5 I_{dc}	0·5 I_{dc}
—peak (inductive load)	—	1·0 I_{dc}	1·0 I_{dc}
—peak (resistive load)	3·14 I_{dc}	1·57 I_{dc}	1·57 I_{dc}
—r.m.s.	1·57 I_{dc}	0·725 I_{dc}	1·11 I_{dc}
Peak inverse voltage A	3·14 V_{dc}	3·14 V_{dc}	1·57 V_{dc}
across rectifier B	2·83 V_{ac}	2·83 Vac	1·41 Vac
R.m.s. secondary voltage	2·26 V_{dc}	1·13 V_{dc} *	1·13 V_{dc}

V_{dc} = output voltage I_{dc} = output current V_{ac} = input a.c. voltage
* Each half of the h.t. winding.
A = choke input B = capacitor input

Voltage Multiplier Circuits

The voltage multiplier is a form of rectifier circuit where the output voltage may be two or more times that obtained from the conventional half-wave or full-wave rectifier with capacitor input when supplied with the same ac input voltage. A combination of rectifiers and capacitors is used such that the capacitors are charged in parallel via the rectifiers and then discharged in series, the rectifiers acting as switches in addition to their normal function. The regulation of these circuits is poor as a result of this mode of operation, but the use of large value capacitors will assist in maintaining a reasonable regulation if the load varies appreciably.

Half-wave and full-wave voltage doubler circuits are illustrated in **Fig 4.5a** and **b**. The full-wave circuit has better regulation but has the disadvantage of not having a common input and output terminal. As in all full-wave circuits, the ripple component is at twice the supply frequency and is therefore easier to remove. At zero load, the output voltage is very nearly twice the peak value of the input ac voltage but falls rapidly to a value approximately twice the rms input voltage when appreciable current is drawn. The regulation may be improved by increasing the size of the capacitors, but care should be taken to ensure that the peak current ratings of the rectifiers are not exceeded. Semiconductor rectifiers are more convenient for use in these circuits although valve rectifiers may be used if desired.

Voltage tripler and quadrupler circuits are illustrated in **Fig 4.5c** and **d**. The tripler is a form of half-wave circuit where the output of a half-wave doubler is added to a normal half-wave rectifier. The quadrupler circuit is also known as the Cockcroft-Walton multiplier and, if required, additional stages may be added to provide higher output voltages.

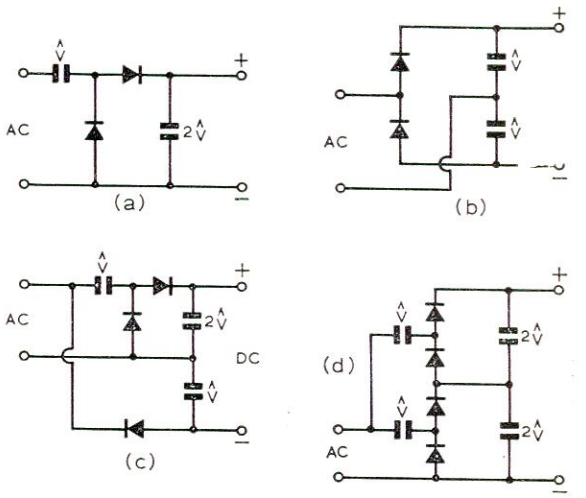


Fig 4.5. Voltage multiplier circuits.
(a) Half-wave voltage doubler.
(b) Full-wave voltage doubler.
(c) Voltage tripler.
(d) Voltage quadrupler.
V—the peak value of the ac input voltage. The working voltages of the capacitors should not be less than the values shown.

When used to provide appreciable currents (up to 50–60mA) the capacitors shown in the circuits of **Fig 4.5a, b** and **c** should be at least 8 μF and preferably 16 μF to provide reasonable regulation of the output voltage. Lower values (0·1 to 0·5 μF) will be satisfactory when the load is not more than 1–2mA as in eht supplies. The polarity of the output voltage may be reversed in all the circuits shown by reversing the connections to each rectifier.

Types of Rectifier

Semiconductor and valve rectifiers may be used in the circuits described in the previous section. Semiconductor rectifiers have the advantage of low voltage drop and do not require heater power, but are more susceptible to breakdown when misused, particularly in respect of excessive operating temperature and peak inverse voltage. Generally speaking the semiconductor rectifier is preferred for use in low voltage high current supplies where the bridge connection is normally employed and in eht supplies, particularly when

one of the various types of voltage multiplication circuits is employed. In passing it may be noted that the terminal of a semiconductor diode corresponding to the cathode of a thermionic diode is marked + or carries a red colour indication.

The valve rectifier is manufactured in a great variety of types and ratings suitable for almost any application in amateur equipment. They may be divided into two types—high vacuum or gas- or mercury-vapour filled, each having its particular field of usefulness.

The high vacuum rectifier is available in both half-wave and full-wave types, the latter consisting of two diodes in the same envelope with a common cathode and heater assembly. The indirectly heated type of low-power rectifier is preferred although the earlier directly heated types are still used. The indirectly heated type warms up at sensibly the same rate as the other indirectly heated valves in an equipment and so avoids the application of high no-load ht line voltages to the circuit. Some types of indirectly heated rectifiers will withstand heater-to-cathode voltages of up to 650V peak and are provided with 6·3V heaters, thus permitting the use of the same heater winding for all valves, eg in a receiver or test equipment. The vacuum rectifier is characterized by a relatively high internal resistance between anode and cathode which renders it less susceptible to damage from temporary overload.

The maximum dc load current available from the larger type of full-wave rectifiers is 250mA, and the maximum ac input voltage to each anode is 600–1,000V, dependent upon the type of filter circuit employed. The two anodes of a full-wave rectifier may be paralleled via current equalizing resistors of 50–100Ω if higher current output is required. Two such valves used in the full-wave circuit will provide twice the output current of one valve, with some improvement in regulation.

Gas-filled or mercury-vapour rectifiers are used when the current and voltage requirements are in excess of the ratings of high vacuum types. They are normally directly heated half-wave types so that two valves are required in the full-wave circuit. Both gas-filled and mercury-vapour rectifiers have a low internal voltage drop of 10–20V independent of load current. In the case of mercury-vapour types there are certain operating limitations which must be observed, eg the ht voltage must not be applied until all the liquid mercury within the bulb has been vapourized by pre-heating the filament, and the bulb temperature must be kept within prescribed limits set by the manufacturer. Non-observance of these points entails premature failure of the rectifier. Gas-filled types are less critical in operation but the filament must be allowed to reach its normal operating temperature before applying ht.

Gas-filled valves and to a lesser extent mercury-vapour types can produce oscillation noise and for this reason block-bias switching of transmitters may, at frequencies below about 3·5MHz give rise to excessive noise in a nearby receiver. This noise does not, however, appear on the carrier as it occurs only when the valves are virtually non-conducting.

Rectifier Ratings

Valve and semi-conductor rectifiers are subject to limitations in respect of peak inverse voltage and peak current handling capability, both when delivering power to a load and when switching on. In this connection it should be noted that when ht voltage is applied to a rectifier (assuming the cathode is at normal operating temperature in the case of a valve) having a capacitor input filter, the capacitor when uncharged presents a virtual short-circuit to the rectifier. Under these conditions a very large current flows, limited only by the internal impedance of the transformer and the rectifier itself until the capacitor is charged. In order to ensure that an acceptable life is obtained from the rectifier the manufacturers provide recommendations in respect of the minimum value of series impedance which should be present to limit this surge current to a safe value. This information is often presented in the form of rating charts, from which suitable operating conditions may be selected with a minimum of calculation. A study of the manufacturers' data on maximum ratings will be well repaid in long life when the rectifier is correctly chosen and the associated circuitry so designed that none of the ratings are exceeded.

Operation of Rectifiers

It is important to ensure that the filament or heater of the valve rectifier is operated at the correct voltage, measured at the valve pins. Reduced life expectancy and performance will occur if the heater or filament is under-run. The larger type of valve rectifier takes considerable heater or filament current and an adequate gauge of wire should be used when wiring up the valve-holder.

It is desirable to mount rectifier valves, whether vacuum, mercury-vapour or gas-filled types, in the vertical position with base downwards, to assist ventilation and avoid short-circuits due to a sagging filament touching the anode, particularly when low impedance directly heated rectifiers are employed.

When mercury-vapour rectifiers are first put into service or after a prolonged period of storage, they should be operated at normal filament voltage for at least 30min prior to applying the anode voltage. This is to ensure that any liquid mercury which has become attached to the filament is evaporated, as otherwise arc-back may occur with consequent damage to the filament and its oxide coating. After the valve has been put into operation, a heater warm-up time of 30–60s will be adequate before anode voltage is applied. The use of a thermal delay switch to delay application of the ht voltage to the rectifier valves until the heaters have warmed up is recommended.

Silicon Rectifiers

Silicon rectifier diodes are rapidly replacing thermionic rectifiers, especially as the small size and relative lack of heating results in smaller and cooler-running power supply units.

Silicon diodes as with all other types of semiconductors do not tolerate excessive voltage or current transient surges, and it is necessary to protect these rectifiers against transients which may arise from power system switching on the power company's distribution network, lightning striking the power lines directly or by induction, or switching on or off the supply to the transformer.

With any rectifier having a low forward resistance (eg silicon, gas-filled or mercury-vapour rectifiers) consideration must be given to the effect of operating into a capacitive load such as that presented by the reservoir capacitor of the

conventional ripple filter. At the moment of switching on, the reservoir capacitor represents an almost direct short-circuit across the output of the rectifier. Additionally, if the value of the capacitor is high, then large peak currents will flow during the relatively short duty-cycle of the rectifier. The peak current which will flow at switch-on will depend upon the precise moment in the ac cycle when the switch is closed; the worst possible conditions occur when the switch closes exactly at the peak of the sine wave. A silicon rectifier has no protective warm-up time so that it is possible for a heavy surge of current to flow into the reservoir capacitor.

As with mercury-vapour and other low-impedance rectifiers, this problem can be largely solved by using a choke-input rather than a capacitive-input, ripple filter; this change will also improve voltage regulation, though at the cost of some lowering of dc voltage output. However, a choke is a bulky and fairly expensive component and there are many applications where this solution is inconvenient. In such circumstances it is highly advisable to fit a surge limiting resistor between the rectifier and the reservoir capacitor, even though this results in some loss of rectification efficiency and the generation of additional heat. An acceptable value for a surge limiting resistor is roughly 15 to 30 ohms per diode.

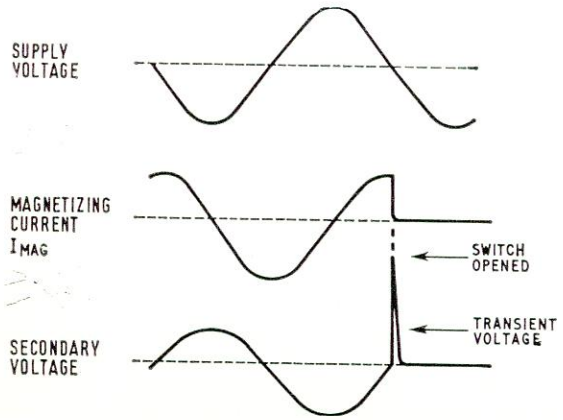


Fig 4.6. Switch-off transient generated from transformer or choke.

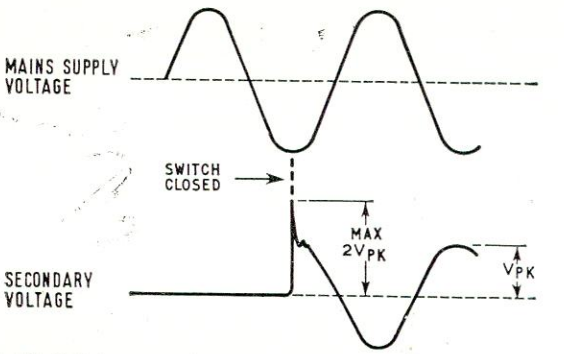


Fig 4.7. Switch-on transient generated from transformer or choke.

Transient voltages are generated whenever a magnetic component (such as a transformer or choke) is energized or de-energized. For example, transient voltages of a peak amplitude several times the normal value can be generated through the sudden interruption of current by switching, see **Figs 4.6** and **4.7**.

There are two main design problems; to make sure that normal working conditions are well within the piv rating of each diode; and to limit high voltage and current surges to a safe working level.

Some makers distinguish between these two problems by adopting the term "crest working voltage" (cwv) for the maximum peak voltage which occurs under normal repetitive conditions as opposed to the transient rating which is a higher voltage which can be accepted for a momentary period.

Calculating piv Ratings

The first step when considering the design of a power supply using silicon diodes is to calculate the basic peak inverse voltages (that is crest working voltages) which will appear across each diode. **Fig 4.8** shows the situation for the most commonly used circuits; these theoretical figures ignore transformer and rectifier voltage drops, etc but this is of little practical importance in the power units under discussion.

Consider the bi-phase or full-wave circuit of **Fig 4.2b**. The piv across each leg of the rectifier is approximately equal to $2\sqrt{2}$ (about 2·8) times the alternating voltage (measured in rms) across each half of the transformer secondary winding. Thus with a 350–0–350V transformer, the piv across each rectifier section will be roughly 2·8 × 350V, which is 980V. To provide a reasonable margin of safety, it will be advisable for each section to have a piv of about 1,200V. A single diode with this rating would tend to be rather expensive; in practice, two 600 piv or 800V piv types would be used. The use of diodes of mixed ratings is not recommended.

In this calculation it has been necessary to distinguish between the ac input to the rectifiers and the theoretical dc output. This is because the multiplication factor to obtain the piv from the theoretical dc output is 3·14, appreciably higher than the 2·8 used.

Voltage equalization is required when a number of diodes are connected in series as the reverse resistance of silicon diodes varies appreciably. This problem can be overcome by connecting an equalizing resistor across each diode (as should be done incidentally for series-connected VR-tubes and electrolytic capacitors), see **Fig 4.9.** The value of the resistor must be relatively small compared with the reverse resistances of the diodes. The peak inverse voltages are then shared almost equally between the diodes despite any differences in the diodes themselves. A typical value would be 300 to 400Ω/V of the piv rating of the diode. These resistors will, of course, allow a certain amount of ac to bypass the diodes but this forms only a small part of the ripple current.

Even with equalizing resistors it is advisable not to operate series-connected diodes right up to their full piv ratings if this can be avoided. A good safety margin should be allowed to meet unavoidable current and voltage surges.

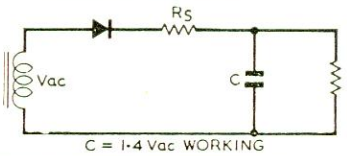
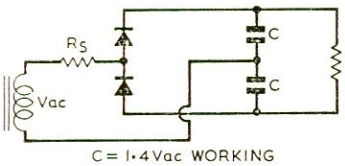
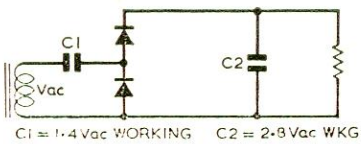
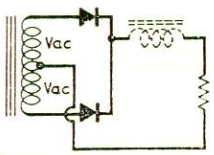
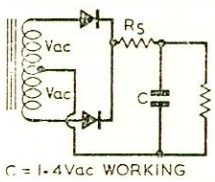
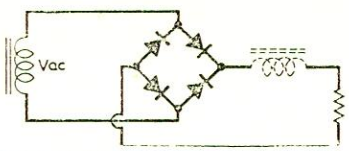
Circuit		P.I.V. Across Diode	Max. Vac Related to Diode P.I.V. Rating	Max. mean D.C. Output Current Related to Diode Rating	Approx. Mean D.C. Output Related to A.C. input voltage
Basic Single Phase Half-Wave Resistive Load		1·4 Vac	$\frac{PIV}{\sqrt{2}}$	I	0·45 Vac
Single Phase Half-Wave Capacitive or Battery Load		1·4 Vac	$\frac{PIV}{\sqrt{2}}$	0·8 I approx.	1·4 Vac* (Maximum)
Single Phase Voltage Doubler Symmetrical		2·8 Vac	$\frac{PIV}{2\sqrt{2}}$	0·8 I approx.	2·8 Vac* (Maximum)
Single Phase Voltage Doubler Cascade		2·8 Vac	$\frac{PIV}{2\sqrt{2}}$	0·8 I approx.	2·8 Vac* (Maximum)
Single Phase Full Wave Resistive or Inductive Load		2·8 Vac	$\frac{PIV}{2\sqrt{2}}$	2 I	0·9 Vac
Single Phase Full Wave Capacitive or Battery Load		2·8 Vac	$\frac{PIV}{2\sqrt{2}}$	1·6 I approx.	1·4 Vac* (Maximum)
Single Phase Bridge Resistive or Inductive Load		1·4 Vac	$\frac{PIV}{\sqrt{2}}$	2 I	0·9 Vac

Fig. 4.8. Ratings in other connections related to basic ratings.

*** Figures quoted are maximum, i.e. no load. The actual voltage depends on the load and capacitor value. Any voltage drop due to the diodes and the transformer impedance is ignored.**

Note: Vac is in r.m.s. values. RS is a surge limiting resistor.

As an alternative to resistors, equalizing capacitors, **Fig 4.10**, may sometimes be recommended for this purpose, forming an ac potentiometer.

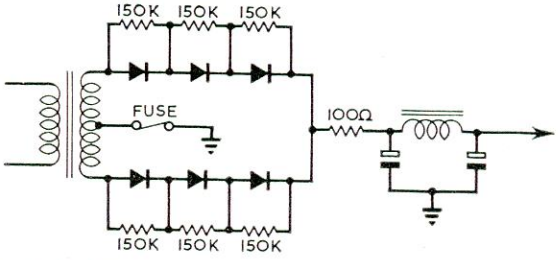


Fig 4.9. Typical power supply using series connected silicon diodes illustrating some of the precautions discussed in the text.

There are various circuit methods of reducing the effects of transients arising from switching surges and mains overvoltages.

One of the most satisfactory methods of restricting these is to connect suitable series connected capacitors and resistors across either primary or secondary of the power transformer.

Suitable values for these components can be calculated from the following expressions.

For use across the primary:

$$C = \frac{100\ \text{Imag}}{V}\ \mu F$$

$$R = \frac{150}{C_{\mu F}}\ \text{ohms}$$

For use across the secondary:

$$C = \frac{225\ \text{Imag}\ T^2}{V}\ F\mu$$

$$R = \frac{200}{C_{\mu F}}\ \text{ohms}$$

where

Imag = Magnetising rms current.
(For this purpose a value of 10 per cent of the primary or secondary as appropriate may be used.)

V = Transformer primary rms voltage.

$T = \text{Transformer}\ \frac{\text{primary}}{\text{secondary}}\ \text{rms voltage}$

Controlled avalanche rectifiers are likely to be increasingly used, these have a carefully controlled non-destructive internal avalanche breakdown to protect the junction.

Temperature Effects

The characteristics of silicon junction rectifiers, like those of other semiconductor devices, are sensitive to changes in temperature. Although silicon diodes can be used at temperatures well above the boiling point of water (100°C), the maximum safe dc output current falls quite rapidly with increasing temperature, so the maximum output of silicon diodes must be reduced with increasing ambient temperature.

The extent of the derating necessary can be quite severe although the figures vary a little with type. Thus a 250mA diode might have to be restricted to about 100mA if required to operate at a high temperature.

The amount of heat generated in the rectifier itself is low, so that it should usually be possible to ensure that the diodes run cool. They should be mounted so that a reasonable amount of cool air can reach all outside surfaces; they should be kept away from heat producing valves and components. The temperature of any equalizing or surge-limiting resistors can be kept low by fitting generously rated types. Try to ensure that the diodes are not mounted in currents of warm air.

SMOOTHING CIRCUITS

The pulsating dc from the rectifier circuits illustrated in **Fig 4.1** is not sufficiently constant in amplitude to be used to operate equipment directly and means must be provided to smooth out the variations. This function is carried out by means of a combination of series inductors or resistors and parallel capacitors termed a filter or smoothing circuit. As described earlier, the output from the rectifier consists of dc plus a superimposed ac component and expressed in its simplest terms the action of the filter is to separate one from the other and allow the dc to pass to the load while the ac is bypassed and confined to the filter circuit. Apart from its basic purpose of separating the ac and dc components of the rectifier output, the filter has a profound effect upon the operation of the rectifier itself and the dc voltage output, the voltage regulation of the supply and the maximum load current which can be safely drawn depend to a large extent upon the design of the filter.

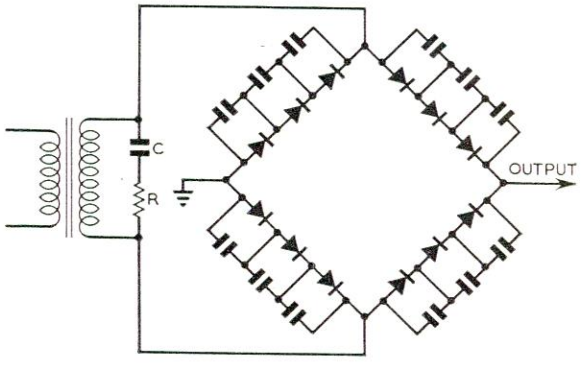


Fig 4.10. Disc ceramic capacitors used as transient suppressors in high-voltage silicon diode power supply. For a 2kV transformer C would be rated at 5kV and the remaining capacitors (0·002μF) 1·2kV. The actual number of diodes in each arm would depend on their piv ratings.

Power supply filters fall into two classifications depending upon whether the first component of the filter network is a capacitor or an inductor (choke). Capacitor input filters are characterized by a relatively high dc output voltage for a given ac input voltage to the rectifier, but the regulation is poor and the rectifier is called upon to handle higher peak voltages and currents than when choke input is used. A choke input filter provides much better regulation when properly designed but the dc output voltage is lower. The resistor-capacitance filter is a variant of the capacitor input filter where resistors replace the inductors. The use of this type of filter is normally confined to low constant current

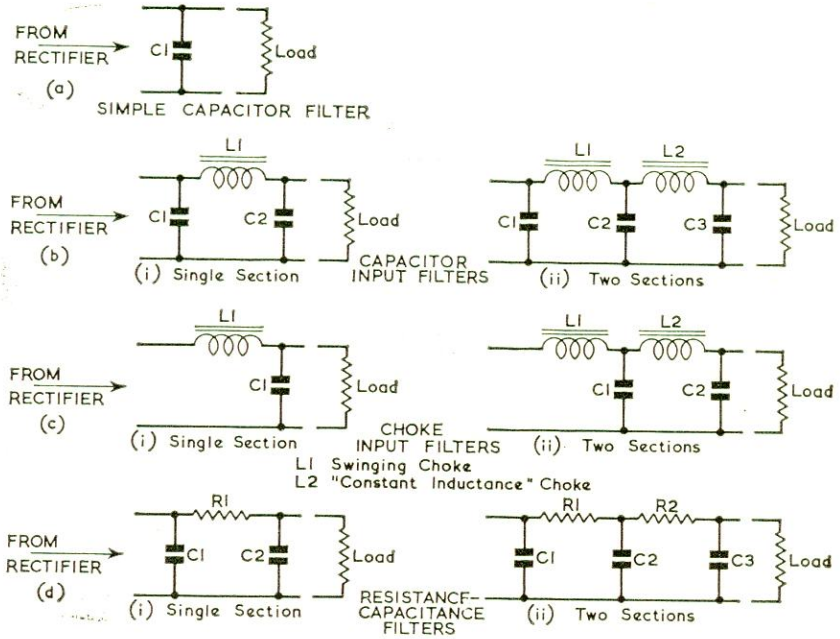


Fig 4.11. Typical filter circuits.
(a) Simple capacitor filter.
(b) Capacitor input filter.
(c) Choke input filter.
(d) Resistor capacitance filters.

applications because of the relatively high voltage drop across the series resistors and consequent poor regulation. Typical filter circuit configurations are shown in **Fig 4.11.**

The Capacitor Input Filter

The simplest form of capacitor input filter is illustrated in **Fig 4.11a** and consists of a single capacitor C1 placed in parallel with the output of the rectifier and the load resistance.

During the periods in which the rectifier is conducting C1 charges up to nearly the peak value of the ac voltage applied to the rectifier, and if no load current were drawn the voltage on C1 would remain constant. When a load is placed across the capacitor, it discharges into the load and the voltage across it falls until the arrival of the next pulse of current from the rectifier which recharges the capacitor to its original voltage. This process is repetitive and the resulting waveform of the output voltage is as shown in **Fig 4.12a** for a full-wave rectifier. Thus the capacitor C1 acts as a reservoir of charge which is depleted by the load and replenished by the rectifier during the period when the rectifier output voltage exceeds the capacitor voltage, **Fig 4.12b**. C1 is therefore known as the *reservoir capacitor*.

The current which flows into C1 from the rectifier is very large and limited only by the internal resistance of the rectifier and the total effective resistance of the transformer

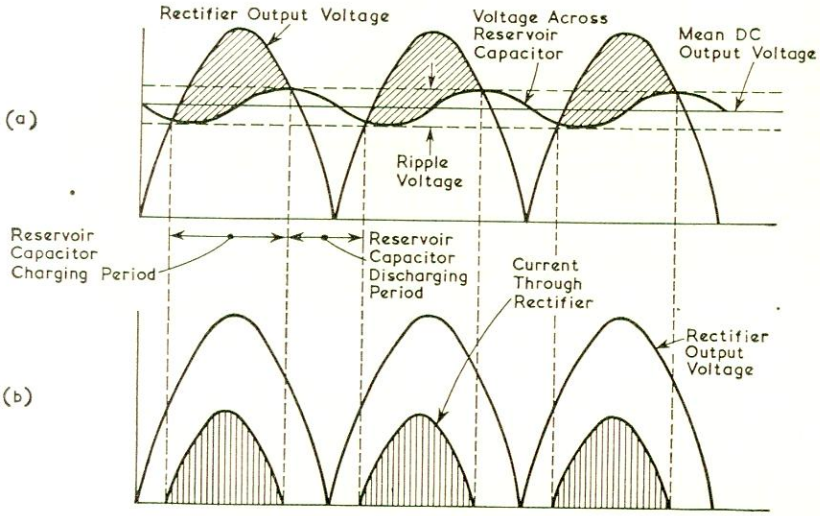


Fig 4.12. Curves illustrating the output voltage and current wave forms from a full-wave rectifier with capacitor input filter. The shaded portions in (a) represent periods during which the rectifier input voltage exceeds the voltage across the reservoir capacitor causing charging currents to flow into it from the rectifier.

windings. In order not to exceed the maximum surge current rating of the rectifier it may be necessary in practical circuits to increase the effective resistance of the transformer by inserting additional resistance between the transformer and the anode or anodes of the rectifier. The total source resistance as seen by the reservoir capacitor will determine how closely the capacitor voltage will approach the peak value of the ac voltage during the charging period, ie the lower the source resistance the more closely the two voltages will approach each other. When a load is connected the capacitor voltage falls between pulses of charging current, the amount by which it falls being determined by the load resistance.

A decrease in the value of the capacitor or load resistance causes a greater fall in voltage. The amplitude of the variation in capacitor voltage or ripple voltage, which varies about a mean value corresponding to the dc output voltage, is therefore determined by the load resistance, and to a lesser extent by the source resistance as well as the value of the capacitor. A graph showing approximate values of ripple voltage expressed as a percentage of the dc output voltage plotted against load resistance is shown in **Fig 4.13** for three typical values of reservoir capacitor.

A reservoir capacitor of 16μF represents the maximum value which should normally be used with a full wave rectifier and 32μF for a half-wave circuit. Increasing these values will produce relatively small improvements in voltage regulation and ripple but are undesirable because of the increased surge current through the rectifier and also because of increased ripple current through the reservoir capacitor. The amount of ripple current flowing is of great importance when an electrolytic capacitor is used as a reservoir, and too high a value of ripple current will lead to overheating and breakdown of the capacitor. A typical value of maximum permissible ripple current is 260mA for a 16μF 450V working electrolytic of plain foil construction and 122mA for an etched foil type. Provided that a dc load current of not more than 120mA is taken when a plain foil type is used and 70mA in the case of etched foil types, there is little danger of exceeding the maximum ripple currents stated.

The dc working voltage of the reservoir capacitor, whether electrolytic or paper, should be at least equal to the peak value of the ac applied to the rectifier, ie $\sqrt{2}$ times the transformer ht secondary voltage in half-wave and bridge circuits and $\sqrt{2}$ times the half secondary voltage in the biphase circuit. The peak inverse voltage which the rectifier must withstand approaches $2\sqrt{2}$ times the ac voltage at light loads in the half-wave and biphase circuits and $\sqrt{2}$ times the ac voltage in the bridge circuit. **Table 4.1** summarizes the voltage and current relationships existing in the circuits of **Fig 4.1.**

Choke Input Filters

The choke input filter is used when good regulation of the output voltage is important, where the maximum load current may be four or five times the minimum. The output voltage obtained is somewhat lower than when a capacitor input filter is used and allowance must be made for this when selecting a suitable ht transformer.

Full-wave rectifier circuits are normally used with choke input filters as the output voltage would be inconveniently

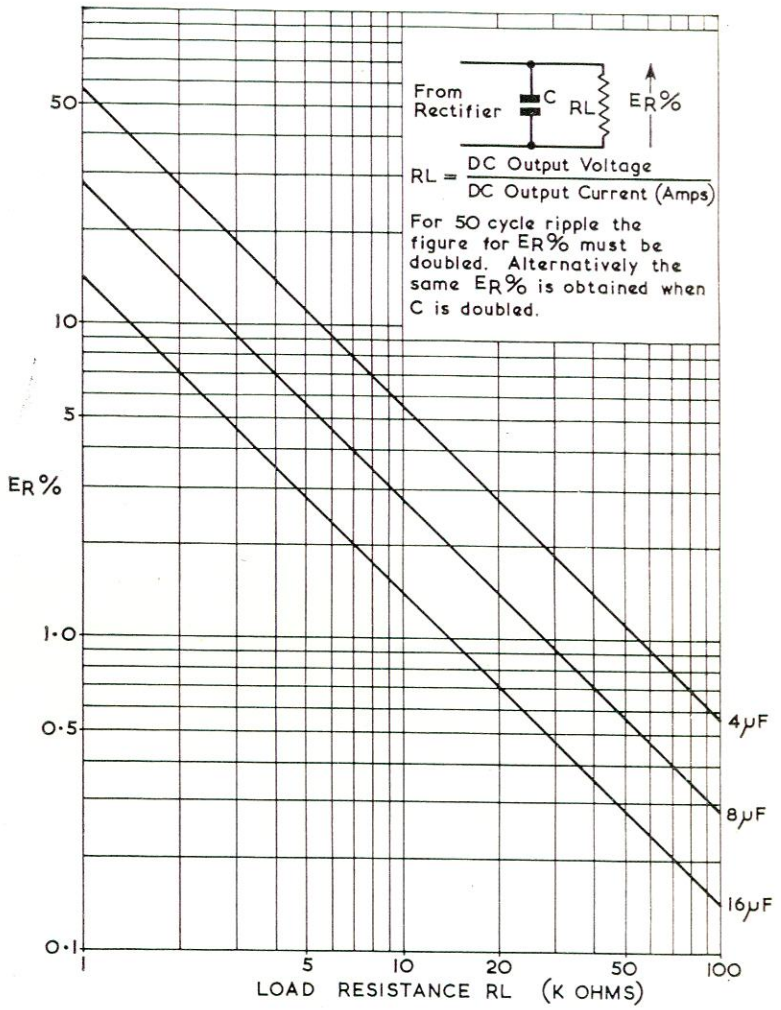


Fig 4.13. Curves showing 100c/s ripple component as a percentage of the dc output voltage across a reservoir capacitor.

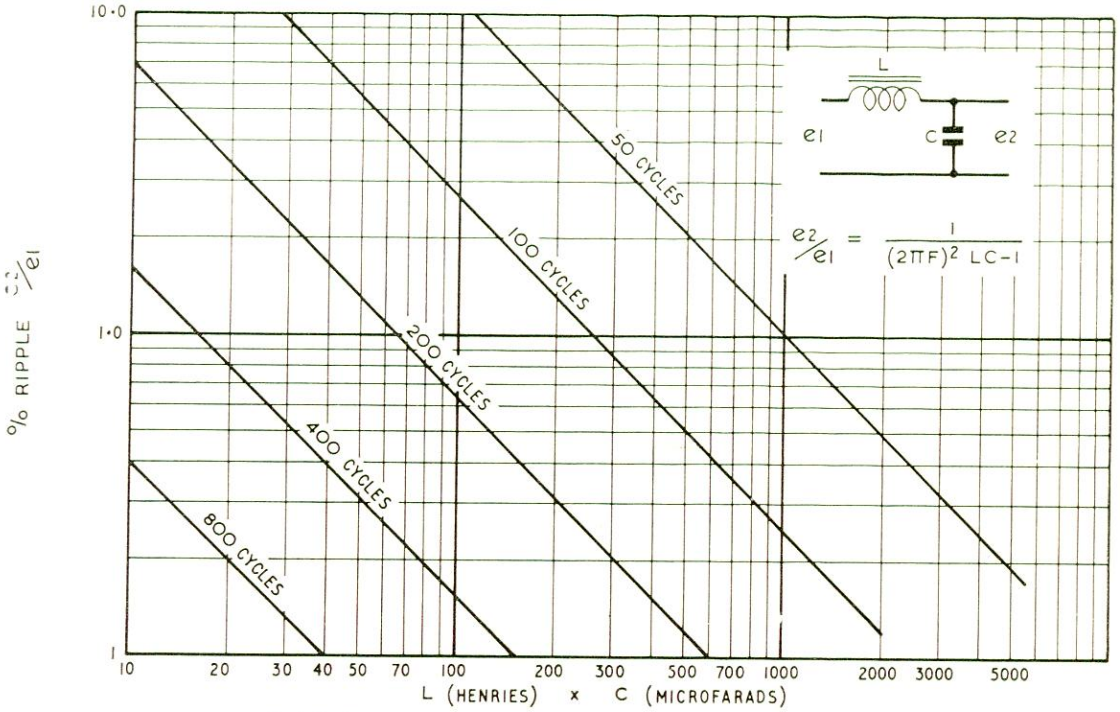


Fig 4.14. Relationship between percentage ripple and product of LC.

low if the half-wave circuit is used. Neglecting the voltage drop in the choke and rectifier, the mean dc output voltage of a choke input filter fed by a full-wave rectifier is 0·9 times the applied ac voltage. The choke input filter is illustrated in **Fig 4.11c** and consists of an iron-cored inductor L1 in series with the load and a capacitor C1 across the load. The action of an inductor L1 is to attempt to maintain a constant flow of current through the rectifier throughout the ac cycle. If the inductance of L1 were infinite the current would be constant, but in practice this cannot be achieved, and some variation of current does occur and appears as a ripple, but provided the peak-to-peak amplitude of the variation does not exceed the dc load current satisfactory constant current operation will be obtained. The minimum value of inductance required to do this is called the *critical inductance*, Lc. Assuming the source resistance as seen by the rectifier is small compared with the load resistance RL (dc output voltage/dc output current), then Lc in Henrys is given by the following equation

Lc = RL/940 for a full wave, single phase, 50Hz supply.

It will be seen from the equation for critical inductance that the value of Lc becomes lower as the load current is increased. This permits the use of a swinging choke for L1 with considerable economy in cost over that of an ordinary "constant inductance" choke. The inductance of a swinging choke is high at low currents falling off to perhaps 20–25 per cent of its low current value as the current flowing is increased to its maximum rating. This characteristic permits the use of a smaller and less expensive component, a typical specification of which would be 25H at 50mA, falling to 5H at 250mA.

If the minimum inductance is insufficient the filter will function as a capacitor input filter with its attendant rise in output voltage at light loads. At light loads, ie high values of RL, the value of Lc required for proper operation would be inconveniently high, and it is usual to connect an artificial load or bleeder resistor across the output of the supply to ensure that sufficient current is drawn at all times to enable a reasonable value of Lc to be used. If the value of Lc has already been determined by available components, then the approximate value of bleeder current required (ie maximum value of RL permissible) is given by the following expression:

$$\textit{Bleeder current in milliamperes} = \frac{\textit{dc output voltage}}{\textit{L MAX (in Henrys)}}$$

where $L\ MAX$ = maximum inductance of the swinging choke.

Further attenuation of the ripple component is achieved by the parallel capacitor C1 and the overall reduction of ripple by a choke input filter is relatively high compared with the capacitor input filter of **Fig 4.11a**. A graph showing the relation between percentage ripple and the product LC in Henrys and microfarads is shown in **Fig 4.14**. Values of L and C which lead to conditions approaching series resonance at the ripple frequency should be avoided as the ripple voltage would build up to high values, which apart from defeating the object of the filter may cause excessive rectifier peak currents and unduly high peak inverse voltages. The product of L and C producing resonance is 2·53 assuming 100Hz ripple and 10·12 assuming 50Hz ripple, and the product of C in microfarads and L in Henrys (maximum current value) should be at least twice these figures.

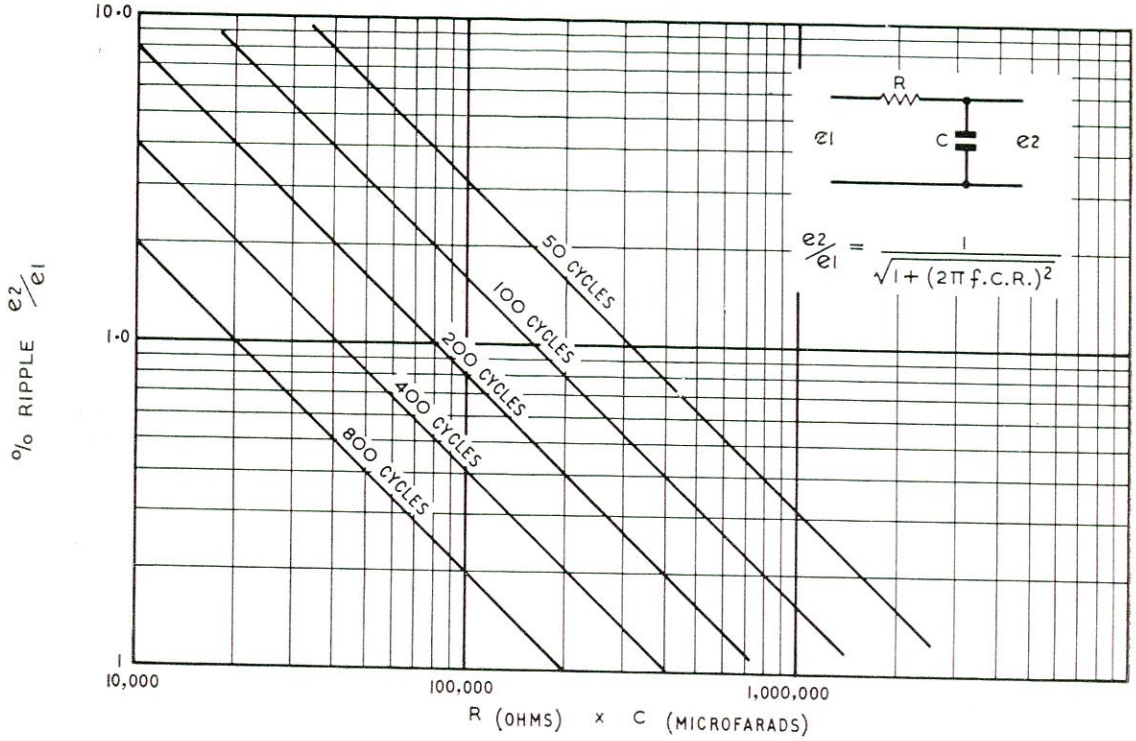


Fig 4.15. Relationship of percentage ripple and product of RC.

The simple capacitor input and choke input filters described will not reduce the ripple voltage to a low enough value for use in power units supplying the low level stages of transmitters and receivers and further *LC* filter sections will be required as shown in **Fig 4.11b** and **c**.

As a guide to the number of filter sections needed the following permissible ripple percentages may be quoted for various types of load:

Cw transmitters	5 per cent
Telephony transmitters	1 per cent
Class B modulators	0·25 per cent
VFOs, speech amplifiers and receivers, ssb generators	0·01 per cent

For most purposes one additional section will be adequate after a choke input filter, and one or two sections, depending upon the required ripple attenuation, after a simple capacitor input filter. The capacitors used in the additional sections should have a working voltage at least equal to, and preferably greater than, the peak ac voltage. The chokes should be constant inductance types rates to provide the required inductance at the maximum current taken by the load.

Resistance Capacitance Filters

The substitution of resistors for inductors in the filter sections following the reservoir capacitor provides an economical and space-saving method of ripple attenuation when the regulation of the supply is not important and the relatively high voltage drop across the series resistors can be tolerated. The ripple attenuation x (where x = output/input ripple) plotted against the values of RC from 10^2 to 10^6 is shown in **Fig 4.15** where RC is the product of series resistance in ohms and parallel capacitance in microfarads. The same requirements regarding the capacitor working voltage apply as when LC sections are used. It is also necessary to ensure that the series resistors are of adequate power handling capacity to avoid overheating. The required value of dissipation in watts may be computed from the usual formula $W = I^2R$ where I is in amperes and R in ohms, and the voltage drop from the formula $V = IR$ using the same units. To reduce the voltage drop, the highest practicable values of C should be used. This will also be advantageous in providing a low impedance path to audio frequencies, so reducing the possibility of low frequency instability when this smoothing system is used in conjunction with multistage audio frequency ampliers.

SELECTION OF A SUITABLE TRANSFORMER

The transformer secondary voltage required for a given dc output voltage is best obtained from the manufacturers' characteristic curves for the rectifier to be used. Due allowance should be made for the voltage drop in the filter chokes, and also for the fall in transformer output voltage when current is drawn. A fall in transformer output voltage from 5 to 10 per cent of the open circuit voltage may be expected at full load. In most instances a commercially manufactured transformer will be employed in amateur equipment and it will be necessary to specify the maximum dc load current

and type of rectifier circuit to be used when ordering an ht transformer.

The source resistance presented to a rectifier is determined by the winding resistance of the ht transformer plus any additional resistance inserted to bring the value up to the minimum required by the operating conditions of the rectifier. The effective transformer winding resistance is given by the following equation:

Effective winding resistance $= N^2Rp + Rs$ *ohms*

where N = transformer turns ratio primary to secondary and Rp and Rs are the dc resistances of the primary and secondary windings. When the transformer feeds a biphase rectifier, the turns ratio from primary to half ht secondary should be taken and also the resistance of half the total ht secondary winding.

The provision of an earthed electrostatic shield between the primary and other windings of mains transformers is recommended. Apart from its basic function of reducing the interwinding capacitance, the shield provides an added factor of safety in the event of breakdown between high voltage windings and the primary of the transformer. Reduction of the interwinding capacitance results in less mains-borne noise being coupled into the equipment via the power supply.

POTENTIAL DIVIDERS AND SERIES DROPPING RESISTORS

Voltages of lower value than that provided by the power supply may be obtained by the use of a potential divider which is a form of potentiometer where the tapping points on the resistor are fixed or adjustable instead of being continuously variable. As many tapping points as desired may be used to give various voltages, but each additional point from which current is taken will affect the voltage at each of the other tapping points. The extent to which the output voltage varies depends upon the current taken from each point and the resistance between the tapping points. The lower the total divider resistance, the better will be the voltage regulation at the tapping points.

By the application of Ohm's Law, it is a relatively simple matter to calculate the resistances of each section of the potential divider network, provided the voltage and current taken at each tapping point is known. **Fig 4.16** shows a typical arrangement with two tapping points at *B* and *A*, providing voltages V1 and V2 at currents I1 and I2. The resistor R3 acts as a bleeder and determines the minimum current I3 flowing through the divider network when the loads at *A* and *B* are removed. A suitable value for I3 would be 10 per cent of the total load, this being a suitable compromise between the degree of voltage regulation obtained and the wastage of current through the divider chain. Having fixed a value for I_3 the procedure is as follows:

Calculate R3 $= V1/I_3$

Calculate R2 $= (V2-V1)/(I_1+I_3)$

Calculate R1 $= (V-V2)/(I_1+I_2+I_3)$

where V = supply voltage and all currents are in amperes.

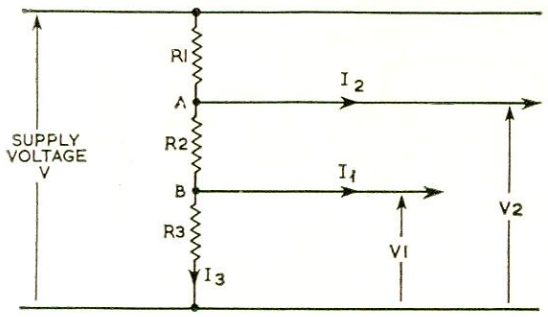


Fig 4.16. Potential divider circuit.

The wattage rating of the resistors may be calculated from the usual formulae, $W = VI = V^2/R = I^2R$, V, I, and R being in volts, amperes and ohms respectively.

In order to utilize the current in I_3, which is otherwise wasted, it may be convenient to insert a suitable relay in series with R1, adjusting the value of the latter appropriately. The relay will operate when the supply voltage is applied and its contacts used to operate other circuits as required. The insulation of the relay should be adequate for the functions its contacts are required to perform.

Where only one reduced voltage is required at constant current, a simple series resistor may be used, the value of which can be calculated as follows:

Required series resistor in ohms $=$

$$\frac{\textit{Voltage dropped across resistor}}{\textit{Current taken by load in amperes}}$$

In many instances it will be found necessary to decouple the load side of the resistor with a suitable capacitor to avoid instability due to the high source impedance presented by the series resistor. Decoupling may also be required at the tapping points of the voltage divider. A capacitor of at least $2\mu F$ will be required to decouple audio frequencies and $0{\cdot}1\mu F$ for radio frequencies.

CONSTRUCTION OF POWER SUPPLIES

The layout and construction of power supplies is by no means critical but there are certain design features which if adhered to will assist materially in producing a reliable and safe unit.

The conventional four-sided chassis, with or without a front panel, has the merit of being readily made up or purchased, and in conjunction with through-chassis mounting components produces a layout where the greater part of the high voltage and mains wiring may be underneath the chassis. A perforated metal cover overall will ensure that exposed high voltage terminals are out of immediate reach.

Input and output connections are preferably made with shielded plugs and sockets, male chassis connectors being used for mains input and female chassis connectors for output. The rear side member of the chassis is convenient for mounting these components. Three pole mains input connectors should always be used when the power supply is built as a separate unit, the third pole of the connector being taken to chassis so that the metalwork is earthed via the three-core mains cable. When the power unit chassis forms part of a rack or cabinet of equipment, each chassis should be bonded together independently of any other connections and earthed, either to the mains earth as above or to a separate properly constructed earth connection. A water pipe must not be used because it is now common practice to use underground plastic pipe.

Double-pole mains switches should be used and wired in next to the mains input so that the units may be isolated completely when changing fuses and making circuit adjust-

ments. When the power unit chassis is to be enclosed in a cabinet or rack, adequate ventilation of heat producing components is essential. Valve rectifiers should be mounted towards the rear edge of the chassis to allow free circulation of air. Semiconductor rectifiers with fins must always be mounted with the fins vertical and preferably over a rectangular hole in the chassis. The more recently introduced wire-ended silicon rectifiers are conveniently wired to tag strips and interconnections made between the tags to produce bridge, biphase or other circuits as required.

Paper capacitors are preferable to electrolytic types where reliability is of primary importance but tend to be expensive when high values and working voltages are called for. It is possible to use electrolytic capacitors by connecting two units of similar capacitance and working voltage in series to produce a capacitor of twice the working voltage and half the capacitance of one unit provided that voltage equalizing resistors of 50–100kΩ are connected across each capacitor. The outer can of the capacitor which is at high potential will be at a potential of several hundred volts above chassis and should therefore be adequately insulated.

When multiple unit electrolytic capacitors are used it should be noted that one unit is often specially processed for use as a reservoir capacitor and care should be taken to ensure that the correct unit is used in this position. Plain foil electrolytics are recommended rather than etched foil types as although somewhat larger physically, they provide a greater factor of safety in respect of working voltage and ripple current. It should not be assumed that the outer case of metal-cased electrolytics is isolated from the electrodes and when used in grid bias supplies or other circuits where the negative terminal is above chassis potential, the metal case should be insulated by means of pvc or polythene sheet wrapped around it, if this is not already provided by the manufacturer.

A bleeder resistor should always be used across the output of a power supply as it provides a means of discharging the capacitors when the equipment is switched off. The resistor used should be of adequate wattage rating, as an open-circuit bleeder is a hazard to safety. The bleeder may form the series resistor for an ht voltmeter. A 5mA meter movement may be rescaled for this purpose and will provide a useful indication apart from its safety function.

Fuses should not be omitted from power supplies as it is false economy to lose a rectifier or transformer as a result of omitting a fuse. The practical power supply circuits show

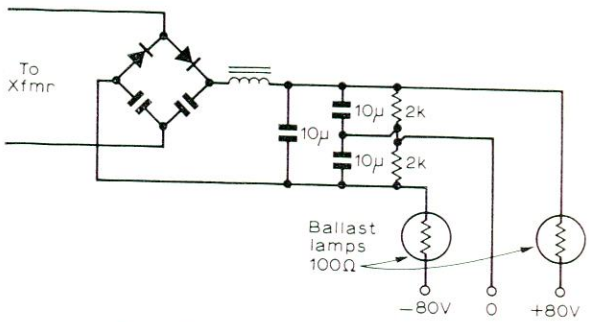


Fig 4.17. Rectifier type 26B. dc circuit.

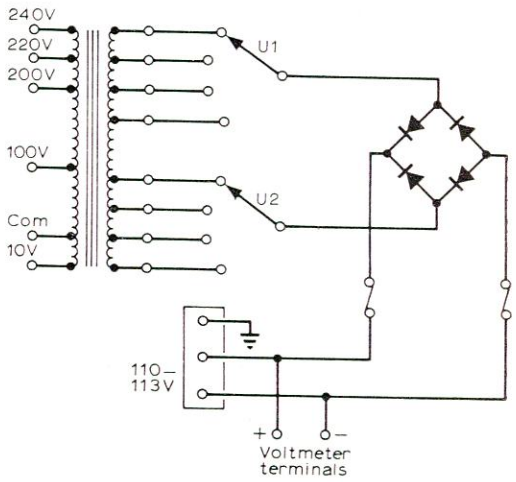


Fig 4.18. Rectifier type 43A.

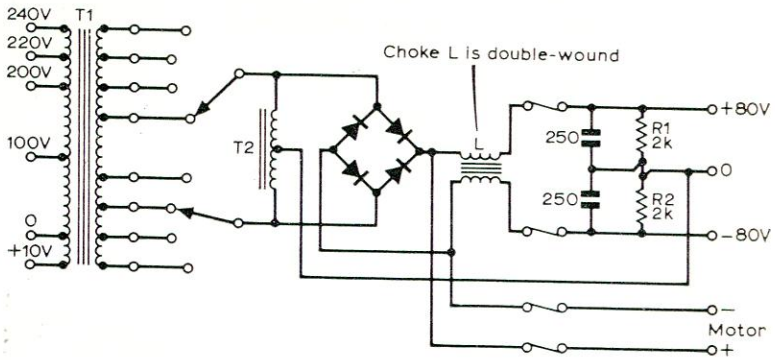


Fig 4.19. Rectifier type 66A.

the points where fuses are most usefully employed. Where large transformers having low resistance primary windings are employed it may be found that the primary fuse blows on switching on due to the high initial surge current; this may be eliminated by the use of a current-sensitive resistor (Brimistor or Varistor) in series with the primary winding. The Brimistor or Varistor has a high initial resistance which falls rapidly as it warms up to a value of a few ohms and may be left permanent in circuit. Similarly a Brimistor may be connected in the ht winding centre-tap or between the rectifier and the reservoir capacitor to prevent the ht fuse blowing at switch-on. Anti-surge fuses are useful in cases where current surges cause trouble with normal type fuses.

Although the layout of components in a power supply unit is not critical electrolytic capacitors and semiconductors should be mounted well away from heat-producing elements.

Adequate spacing of all components is necessary if reliability is to be maintained.

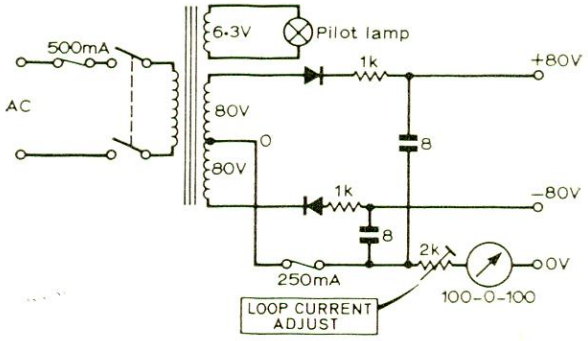
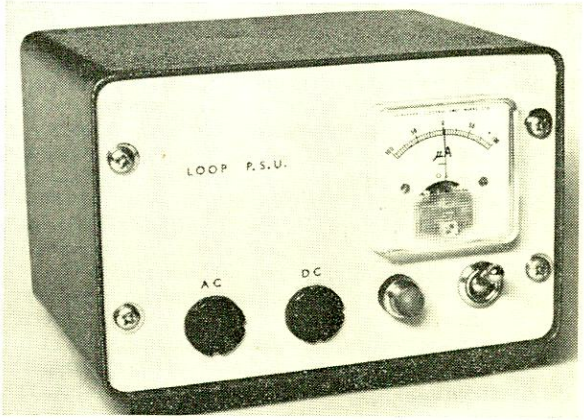


Fig 4.20. Circuit diagram of a simple double-current loop supply. See also illustration below.

The GPO Model 26B Rectifier Unit

The model 26B rectifier is a voltage doubler type, intended to supply a double current telegraph loop. **Fig 4.17** shows the basic circuit. The unit is mounted on a steel base and has a well-ventilated cover; the size is 14in × 10in × 8in. It contains all the necessary transformers and rectifiers to provide the necessary power. It also contains two fuses on the mains side and has two ballast lamps on the output side. The purpose of the ballast lamps is to provide protection if the telegraph line should be short-circuited. The lamps have a low resistance when not lit, but present a high resistance to the short-circuit current when lit. The unit is uncovered by removing the four small screws on the cover and lifting the cover off. Input and output connections are made to tag strips, the leads passing through grommets.



Photograph of simple double-current loop supply. Description overleaf.

Rectifier Type 43A

This unit is a simple full-wave bridge rectifier without smoothing, intended to give 110V dc at 0·7A for motors. The mains input is fed to the mains transformer via a terminal strip and is adjustable in 10V steps over the ranges 100–110V and 200–250V. The secondary is adjustable over a limited range by U-links. If the metal rectifier is a selenium type, the secondary taps are coarse of 12V and fine of 3V. If a copper oxide rectifier is fitted, the taps are coarse of 20V and fine of 5V.

This unit is also on a steel base with a ventilated cover, size approximately 20in × 8in × 7in. The circuit is shown in **Fig 4.18**.

Rectifier Type 66A

A unit which combines both loop and motor supplies is the type 66A rectifier, the circuit of which is shown in **Fig 4.19**. The motor output is unsmoothed current at 160V. The purpose of T2 is to provide a true centre point for the loop supply regardless of the mains transformer secondary tappings. The loop supply is smoothed by a choke and two electrolytic capacitors, and the resistors R_1 and R_2 prevent

the voltage from rising too high on a lightly loaded circuit. A selenium bridge rectifier is fitted.

A Simple Loop Supply

A simple double current loop supply circuit is shown in **Fig 4.20**. The unit is intended to supply enough current to operate a single machine. The loop current adjustment potentiometer should be adjusted to suit the machine in use. The diodes are 400 piv types, and should be capable of supplying about 100mA, to cover surges, transients, etc.

Creed 110/240V DC Motors

This type of motor probably forms the biggest group of motors used in the United Kingdom, and there are several ways in which the dc current can be obtained.

Fig 4.21 shows the circuit diagram of an isolated motor supply and is the preferred method. **Fig 4.22** shows a half-wave alternative version which gives satisfactory results. In both cases the primary and secondary are lightly fused.

In an emergency, the transformer may be omitted, but caution should be taken when working on any part of the motor circuit as there now exists a shock hazard to earth.

Another method of obtaining emergency motor supply dc current for a 240V motor is to simply place a rectifier in series with one motor lead and change the motor voltage tapping to the 160 position, as in **Fig 4.23**. Both these last mentioned methods are not recommended for a permanent installation.

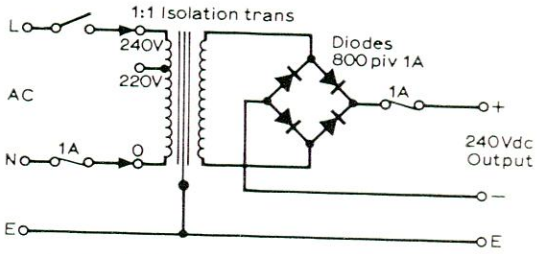


Fig 4.21. Bridge rectifier isolated dc motor supply.

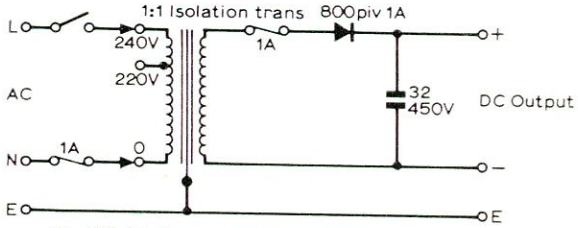


Fig 4.22. Half-wave rectifier isolated dc motor supply.

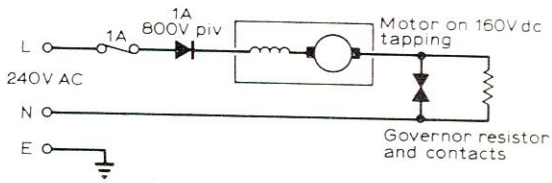


Fig 4.23. Emergency dc motor supply for Creed machines.

CHAPTER 5

RADIO TELEPRINTER DEMODULATORS

THE RTTY SIGNAL

THE rtty signal is received by the front end of the receiver as two rapidly changing frequencies, differing by the *shift* of the signal. In amateur use the shift is usually 850 or 170Hz. The purpose of the demodulator is to convert this frequency shift signal into a pulsing high voltage dc signal suitable for operating the teleprinter magnets and thus causing the machine to print the signal.

Consider the passage of an rtty signal through a communications receiver as shown in **Fig 5.1**.

The signal at point (A) will consist of the two radio frequencies differing by the shift of the signal. Since rtty signals can appear on any frequency it is impracticable to discriminate between these two signals at their transmitted frequency, apart from the fact that the receiver would not be very good, ie both sensitivity and selectivity would be poor.

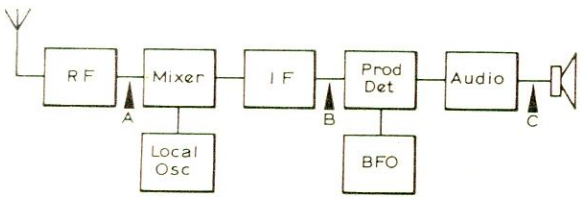


Fig 5.1. Block diagram of a communications receiver showing signal path.

At point (B) the rtty signal will have been mixed down to the received i.f. This situation is illustrated in **Fig. 5.2** for a correctly tuned signal.

If the nominal i.f. is fairly low, say 455kHz or, better still, 85kHz, it is quite easy to discriminate between the two rtty signals. The i.f. strip will provide sufficient gain and the overall selectivity provided by the i.f. should be quite adequate on a communications type receiver.

Several surplus rtty demodulators are available that do provide an output to the teleprinter from the receiver i.f.

Modern commercial equipments take the receiver i.f. and convert it by heterodyne method to a frequency of 10 to 15kHz after which it is limited and detected by a discriminator. This range of frequencies also permits the use of a driven flip-flop or locked multivibrator as a limiter.

Some of these converters also use a "locked oscillator" as a limiter preceding the discriminator. The theory is that the oscillator locks to the receiver i.f. and it is the oscillator output which is fed into the discriminator, so that detection is entirely free from amplitude response. This is a very sound idea but has its practical difficulties. The main one arises from the big amplitude variations of signal that are encountered in radio paths, and the difficulty of designing an inductance-capacitance type of oscillator which will have a dynamic range of locking voltage which may be as high as 100 : 1. To reduce the range required, the locked oscillator is usually preceded by a conventional saturation type limiting stage, and the combination works quite well. While the limiter reduces all signal voltages to a low level, the locked oscillator serves as an amplifier and ensures that the signal fed to the discriminator is at reasonably high level. The peak-to-peak signal output voltage from the discriminator is usually of the order of 6–8V.

As far as amateur construction and use is concerned, however, the most suitable method is to use an audio discriminator. If the rtty signal in the receiver i.f. is mixed with the carrier insertion (or beat frequency) oscillator, an audio signal will result, point (C), that will change rapidly back and forth by the shift of the signal, say 850Hz. All that is required then is to set the bfo so that when the rtty station is tuned in, the mark signal will give one fixed audio tone and the space signal will give another audio tone 850Hz higher. These audio tones are usually fixed at 2,125Hz for mark and 2,975Hz for space (850Hz shift) and 2,125Hz mark, 2,295Hz space (170Hz shift). 2,125Hz and 2,975Hz were chosen for two reasons:

1. They are the fifth and seventh harmonics of 425Hz and hence calibration with a 425Hz tuning fork standard is easy.
2. They define a pass-band of frequencies where no two frequencies are harmonically related.

Thus, to recap, we have seen how it is possible to obtain

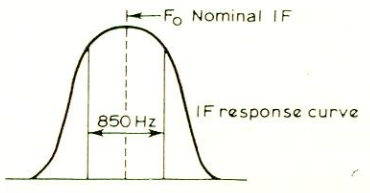


Fig 5.2. I.f. response showing correctly tuned signal.

the shifting audio signal suitable for frequency discrimination in the demodulator.

Design Considerations

We have seen how the rtty signal shifts its frequency and thus a form of frequency discriminator is necessary to separate these two tones and to detect them. An elementary circuit might consist of the arrangement shown in **Fig 5.3**.

L_1C_1 are resonant at 2,125Hz, the mark frequency, and L_2C_2 resonant at 2,975Hz, the space frequency. This circuit gives pulses of negative voltage for mark signals and positive for space signals. These pulses of dc could conceivably be

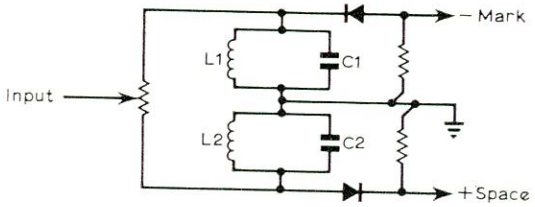


Fig 5.3. Elementary frequency discriminator circuit.

fed into some sort of dc amplifier that would provide sufficient voltage to operate the teleprinter magnets. However, an rtty signal is seldom perfect and a certain amount of additional circuitry must be added around the basic discriminator to give the best results. The signal may fade as a whole and subsequently the output of the discriminator would then depend on signal amplitude as well as frequency. The mark signal might fade with respect to the space frequency (selective fading). This gives rise to bias distortion where the mark and space element lengths are unequal. Interference might appear on an adjacent channel or even *on* the mark or space channels. This is a very relevant problem on today's crowded hf bands. A consideration of the situation that occurs when either the mark or space signals are absent is interesting.

No.	Signals Present	Signals State	Keying Required
1	Mark only	Mark off	Off
2	Mark only	Mark on	On
3	Space only	Space on	Off
4	Space only	Space off	On
5	Both	Mark on	On
6	Both	Space on	Off

Two situations develop where no information is actually present—1 and 4 above. It is impossible to design a system that will take into account these absences fully, as opposite keying action is required in both cases. The fault is in the code employed and several commercial companies have realized this and devised a seven element code that will give greater reliability under these conditions.

However, it is best to allow as little interference as possible into the demodulator before frequency discrimination takes place. To do this a bandpass filter may be placed between the receiver audio output and the input to the demodulator. This should have the effect of attenuating all frequencies outside the range 2,000–3,000Hz.

Two types of home-built filter are illustrated in **Figs 5.4** and **5.5**.

L_2 = half 88mH toroid with 14ft of wire removed.

Very little tuning of this filter is required. The flat top to the passband may be improved by adjusting the capacitance across L_2.

The T-pad attenuator isolates the filter from the receiver loudspeaker coil and also minimizes pick-up of room noise through the loudspeaker. Ceramic capacitors should not be used as these are rather temperature sensitive.

The first and last sections should be tuned to just below 2,125Hz and the middle section to just above 2,975Hz. Adjustment of the 0·015 coupling capacitors should then be made to get the required bandwidth with a reasonably flat top. (If only 850Hz shift is being received a slight dip in the middle will not be detrimental.)

If a 3Ω input is required, the 470Ω and 3kΩ resistors should be dispensed with and a 32-turn link of thin wire wound on to the first toroid.

For "notching out" an interfering signal between the mark and space frequencies, the following circuit will be found very effective, **Fig 5.6**.

The 30k resistor may need to be varied slightly for maximum attenuation. With this filter in circuit and an efficient bandpass filter, a very favourable response curve for rtty reception will be formed, **Fig 5.7**. A more detailed coverage of filters is given later in this chapter.

The overall selectivity of the receiving system deserves some comment at this point. It might be considered that the insertion of a sharp cut-off bandpass filter between the

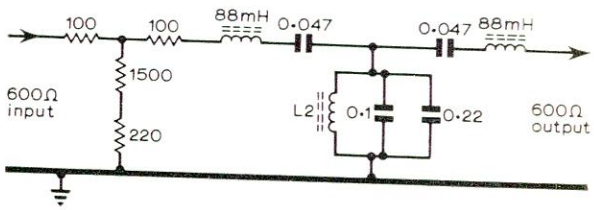


Fig 5.4. Terminal unit input bandpass filter.

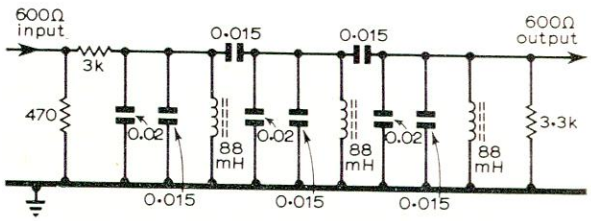


Fig 5.5. Alternative input bandpass filter.

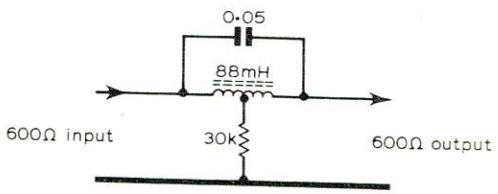


Fig 5.6. 600Ω notch filter.

receiver and demodulator would reduce the necessity of having a narrow i.f. bandwidth in the main receiver. This is not so, however, as the following example will show:

Suppose the receiver has an i.f. bandwidth of, say, 5kHz and an rtty signal is centred on the passband. Suppose there is cw interference 5kHz hf of the rtty signals. **Fig 5.8** shows the situation.

The interference will produce a beat-note of 2,450Hz right in the middle of the mark and space tones. This will upset the operation of the demodulator. The i.f. bandwidth

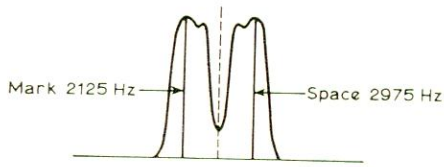


Fig 5.7. Input filter response showing effect of notch filter.

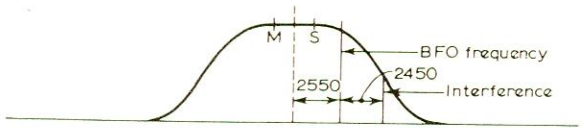


Fig 5.8. I.f. response curve showing effect of receiver bfo on in-channel interference.

should be roughly twice the shift (to preserve good keying waveform), ie about 1,600Hz for wide shift and 300Hz for narrow shift. With narrow filters, tuning of the rtty signal becomes critical to avoid unequal mark and space amplitudes and the stability of the receiver must be excellent. The stability of a crystal controlled tunable i.f. receiver is usually sufficient, the stability of the more modern L/C oscillator front ends will probably be adequate after several minutes' warm up. If the stability is inadequate automatic frequency control should be tried.

LIMITERS

It was mentioned above that two types of fading can occur:

(*a*) The mark and space signals fade simultaneously.

(*b*) The mark and space signals fade independently.

Both of these conditions will have an adverse effect on the action of the frequency discriminator circuits. Overall fading will result in the output of the discriminator being amplitude as well as frequency dependent. This is undesirable. Selective fading can cause element uncertainty—if a mark signal is being sent at the same time as propagation causes the mark signal to fade then the discriminator will have no information. In the case of simultaneous fading the limiter can cope, amplifying it when it falls and clipping it when it rises. Hence the amplitude of the signal at the output of the discriminator will be constant. This condition will not occur if the signal is below the noise level or if there is any interference. This is a vital point and will be considered later.

Consider the action of a limiter on a selectivity fading signal. Suppose the space signal fades away while the mark signal is still present. The mark signal will be captured by the limiters and the weak space signal will be further excluded. This will give rise to unequal mark and space element lengths. If there is interference on or adjacent to the rtty channel then there is the possibility of this interference being held by the limiters to the exclusion of the rtty signal. The same effect can occur if the rtty signal is on or below the noise level, the limiters capture the noise and not the rtty signal. Under these conditions the receiving system is worse off with limiters than without. Thus it is desirable to limit the signal if it is above the noise level and if there is little interference. However, as the noise increases, it is better to employ "limiterless" action.

In order to make use of the good signal-to-noise characteristics of an fsk transmission and to enable the discriminator in the terminal unit to operate at maximum efficiency, any amplitude modulation of the carrier due to noise or variation of the overall frequency response of the receiver must be reduced to a very low level. This is because the output of the discriminator would be influenced by both amplitude and frequency variations and so could produce undesired output.

There are many types of amplitude limiters, and a few of these are described here.

In **Fig 5.9**, V1A acts as a straightforward audio amplifier. V1B is the clipper. Negative going input signals are limited as the anode voltage of V1B is set by the potential divider made up from R5 and R6.

Fig 5.10 shows a limiter employing 6BN6 gated beam pentodes. The 6BN6 may be found to be slightly microphonic and if so, should be mounted on a special shock-absorbing base. The series grid-resistors must be mounted

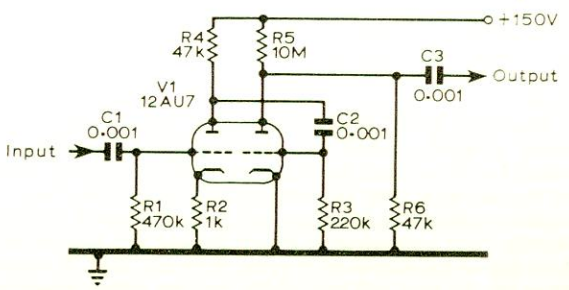


Fig 5.9. Double triode limiter.

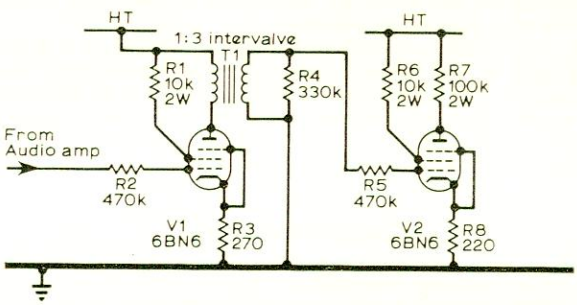


Fig 5.10. 60dB limiter using two 6BN6 valves.

immediately next to the valve-holder pins to avoid hum pick-up and the whole assembly surrounded by a screen. This limiter will give up to 60dB limiting without losing control of the signal.

Diodes may be used as limiters although the range of limiting is not as great as in the limiter described in **Fig 5.10**. In **Fig 5.11** 1N69 diodes were originally specified, but OA81 may be substituted. The diodes are biased by the 150/100kΩ potential divider to 0·3V and clip both the positive and negative going halves of the sine wave input signal. The output from the limiter should be fed to a suitable voltage amplifier to provide a constant high level output with which to feed the discriminators. The limiting range of this design is about 30dB.

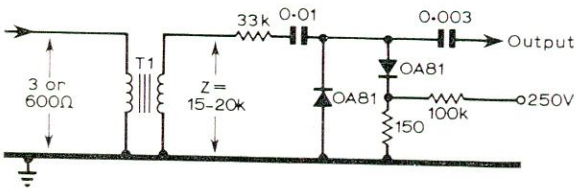


Fig 5.11. Diode limiter circuit.

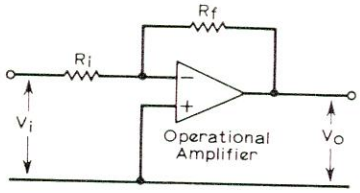


Fig 5.12. Operational amplifier basic circuitry.

The most recent developments with limiters have been those designed around the integrated circuit operational amplifiers. Using only one such operational amplifier, 60dB of limiting may easily be obtained. Briefly, the ideal operational amplifier may be understood to be dc coupled, to have infinite input impedance so as not to load any source, and zero output impedance so it could drive any load. It would have infinite gain and bandwidth, and the output would be exactly determined by both the input signal and by the properties of the feedback circuit. The nearness to these ideals is directly related to cost, but for use in amateur radio teleprinter equipment, the inexpensive versions, such as the 709 type, give excellent results.

The overall gain of a stage using these amplifiers is determined by the values of the feedback components, and assumes that the amplifier is inverting. In **Fig 5.12** the input and feedback resistors are referred to as Ri and Rf respectively, and the output voltage Vo would be equal to the input signal Vi multiplied by the ratio of Rf/Ri.

DISCRIMINATORS

The frequency discriminator circuit is a circuit the output voltage of which is dependent on the frequency of the input signal. A frequency discriminator circuit is found in every fm broadcast receiver. The basic circuit is given in **Fig 5.13**. C1L1, C2L2 determine the frequency range over which the discriminator will operate. The response curve of the voltage appearing across the load resistors is shown in **Fig 5.14**.

In demodulator design, 88mH toroid coils are usually used as the inductors. The input signal is fed in by a potential divider, **Fig 5.15**. Because of the relatively high Q of the tuned circuits, the output voltage will only be present near the two resonant frequencies, **Fig 5.16**. This means that the shift of the signal being received must be exactly 850Hz or very low voltage output will result. Also, the receiver tuning is very important. For less critical operation a certain amount of resistive damping should be applied as shown in **Fig 5.17**.

An alternative solution to damping the tuned circuits is to construct separate flat-topped bandpass channel filters for the mark and space tones. **Fig 5.18** shows the effect. In this case, each channel is, say, 50–100Hz wide, thus allowing for considerable mis-tuning or drift, without impairing the operation.

If the frequency discriminator is of the linear type, it is in theory possible to copy any value of shift from the maximum of 850Hz down to a few cycles. The limiting factor here is the

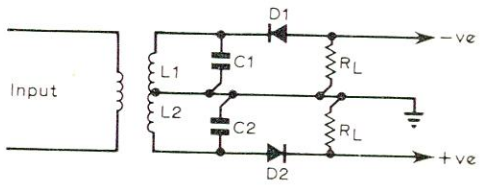


Fig 5.13. Basic circuit of a frequency discriminator.

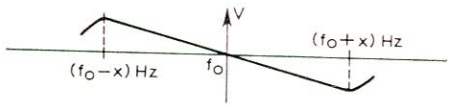


Fig 5.14. Frequency discriminator load resistor voltage curve.

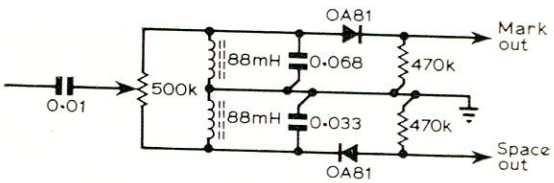


Fig 5.15. Potential divider signal input feed.

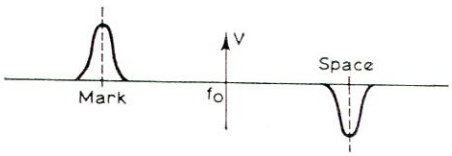


Fig 5.16. Output voltage across resonant tuned circuits.

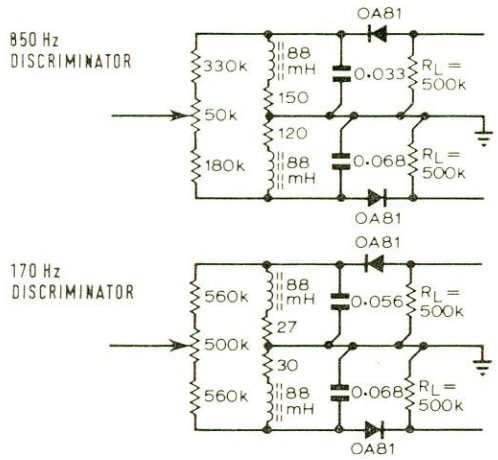


Fig 5.17. Wide and narrow shift filters showing resistive damping.

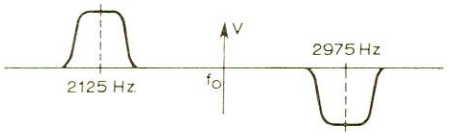


Fig 5.18. Response curves of separate flat-topped bandpass channel filters.

sensitivity of the dc amplifying stages following the detector as the voltage output from a detector of this type with a shift of 170Hz will be quite low.

DETECTORS

The simplest possible detector is a diode with a load resistor and a capacitor to filter out any residual audio frequency. **Fig 5.19** shows how such a simple detector may be used. When L_1C_1 resonates, a negative voltage appears across R_1. When L_2C_2 resonates, a positive voltage appears across R_2. A modification of this circuit is to add another pair of diodes to provide a voltage doubler circuit as in **Fig 5.20**.

However, the presence of the detector circuitry will have the effect of lowering the Q of the tuned circuits preceding it. Thus it is best to feed the output of the discriminators into a class A amplifier and drive the detectors from the amplifier output. Since in this case the discriminators will be feeding into a high impedance load their Q will not be affected.

It is important to have a finely balanced detector. This implies that an output of X volts on either mark or space from the discriminator will give the same output voltages $-y$ and $+y$ from the detectors. To achieve this, it is necessary to use well matched diodes and close tolerance resistors to achieve a symmetrical output with respect to earth. Such a circuit is the parallel combined detector. Two of these are usually used to provide mark and space voltages of identical polarity for a tuning indicator or an autostart stage, as shown in **Fig 5.21**.

It can be seen that this detector in fact consists of two separate detectors D_1, R_1, C_1, D_3, R_2, C_3 and D_2, R_3, C_2, D_4, R_4, C_4 which give outputs of different polarities for a given mark and space input. The particular detector is selected by means of the "Reverse-Normal" switch. Diodes D_5 and D_6 are connected back to back between these detectors and no matter which detector is in use or whether mark or space are being sent, the junction of these two diodes will always be negative, thus providing a voltage suitable for autostart or a tuning indicator. VR_1 is adjusted until the negative voltage at the junction of these two diodes is the same if either mark or space is being sent.

LOW PASS FILTERS

The output from the detectors can still contain a certain amount of audio frequencies on top of the detected signal, **Fig 5.22**. As it is most desirable to have as perfect a square wave as possible, it is best to use a low-pass filter following the detectors to remove the last traces of audio. The simplest low-pass filter is just an RC network. If a 50 baud signal is

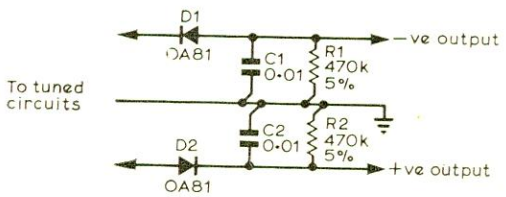


Fig 5.19. Simple detector circuit.

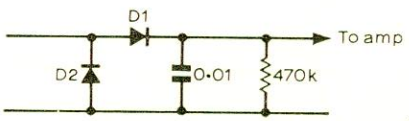


Fig 5.20 Voltage doubler detector circuit.

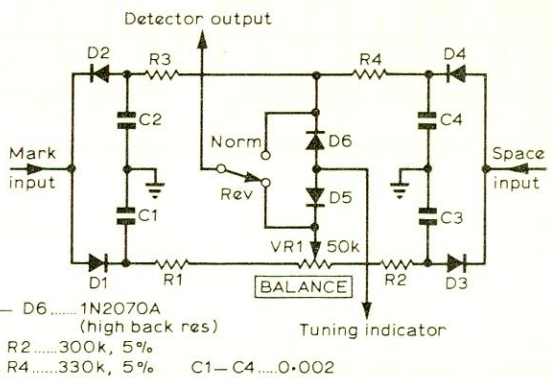


Fig 5.21. Parallel combined detector.

considered, a signal element length is 20ms. Therefore, the frequency of reversals is:

$$\frac{1}{(2 \times 20 \times 10^{-3})} \text{ Hz} = 25\text{Hz}$$

Thus a filter is needed that will accept a square wave pulsing signal of 25Hz, but will attenuate all frequencies above this. However, to retain a reasonably square wave

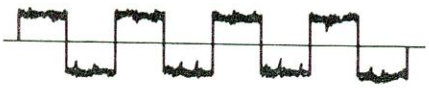


Fig 5.22. Detector output showing dc signal with af superimposed.

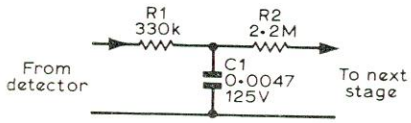


Fig 5.23. Passive low-pass filter.

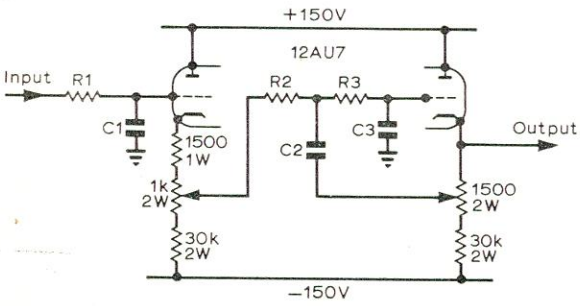


Fig 5.24. Active low-pass filter.

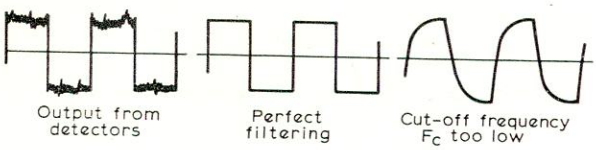


Fig 5.25. Effects of a low-pass filter on detector output.

form, the second and third harmonics of the fundamental frequency should be passed as well. Thus a filter with a cut-off of 75–100Hz is required, as in **Fig 5.23**.

A design for an active low-pass filter by W6SDH appeared in *QST*, November 1966. However, this had been designed for 28Hz cut-off and experiment showed an almost sinusoidal output was obtained from a square wave input. Redesigning for 100Hz cut-off preserved good signal wave form, **Fig 5.24**.

This active filter has three-pole Butterworth transfer characteristics:

Feedback ratio, k = 0·9.

$C_2/C_3 = 7{\cdot}5$

$T_1 = \sqrt{T_2T_3} = 1/2\pi f_c$

$T_1 = \sqrt{R_1C_1}$

$T_2 = R_2C_2$

$T_3 = R_3C_3$

For $C_2 = 0{\cdot}015\mu F$ $C_3 = 0{\cdot}002\mu F$

For $f_1 = 100\text{Hz}$ $T_1 = 1/628 = 1{\cdot}59 \times 10^{-3}\text{s}$

$T_2T_3 = 3{\cdot}98 \times 10^{-2}\text{s}$

Thus: $R_1 = 318\text{k}\Omega$ $C_1 = 0{\cdot}005\mu F$

$R_2 = 2{\cdot}6\text{M}\Omega$ $C_2 = 0{\cdot}015\mu F$ (5 per cent resistors sufficient)

$R_3 = 19{\cdot}5\text{M}\Omega$ $C_3 = 0{\cdot}002\mu F$

The feedback ratio is adjusted by applying 6·3V to the grid of the second half of the 12AU7 and adjusting the 1·5kΩ potentiometer until there is 5·65V on the slider. The 1kΩ potentiometer should be adjusted so there is no output voltage for zero input signal. **Fig 5.25** shows the effect of a low-pass filter.

THRESHOLD CORRECTOR CIRCUITS

The output from the discriminator of a perfect rtty signal will be equally centred about zero. If the signal drifts, the output voltage *swing* will still be the same, but it will not be symmetrical. **Fig 5.26** illustrates the condition.

If the output from the discriminators is not equally centred about zero, bias distortion will occur and cause misprinting. What is required is a circuit that automatically centres the variations about zero, **Fig 5.27**.

The output voltage of the discriminator is applied to two dc restorer circuits, C_1D_1 and C_2D_2, clamping to earth positive and negative swings respectively. The two clamped waveforms are combined in an adding network, R_1R_2, providing the input to a dc amplifier stage.

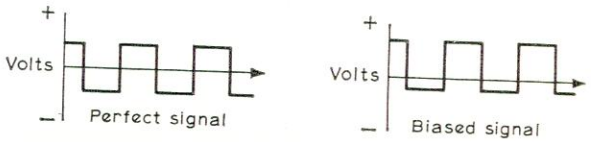


Fig 5.26. Showing discriminator outputs for a perfect signal and for a drifting signal.

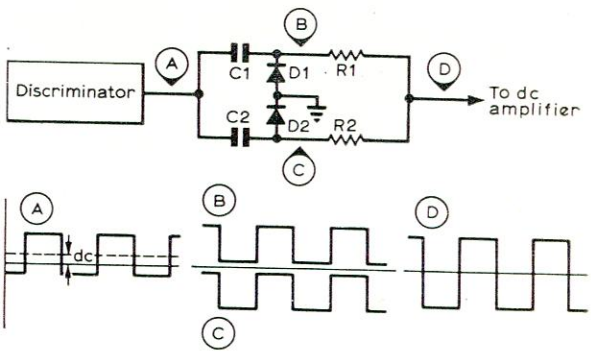


Fig 5.27. Threshold corrector circuit with voltage waveforms at circuit points.

Whatever the dc level of the input waveform, the output will swing symmetrically about earth. However, this basic circuit is ac coupled and hence it will be impossible to receive steady mark or space signals. Characteristic distortion will also occur here as these capacitors will charge differently for different characters. The final circuit includes an additional pair of diodes to cater for long mark or space holds, **Fig 5.28**.

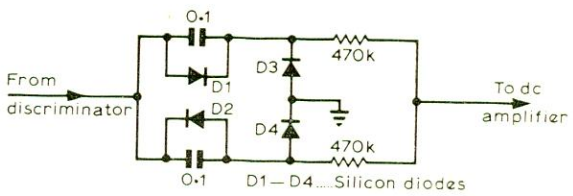


Fig 5.28. Practical threshold corrector circuit.

DC AMPLIFIER AND OUTPUT STAGES

Before the circuitry is discussed, the operating conditions of these stages should be considered.

Teleprinter magnets may be operated in either a neutral or polar circuit (ie single or double current keying). In the former case, the magnet in the teleprinter is held in the marking position and the current pulses force the armature over to the space position against the restoring force of the spring. In polar keying the mark signal causes a current to flow one way through the magnet holding it in the mark position while a space signal will cause a current to flow in the opposite direction, thus causing the armature to move across into the space position.

The loop supplying the magnets may be keyed in several ways:

1. A high speed relay.
2. A valve switch.
3. A transistor switch.

Consider the loop shown in **Fig 5.29**.

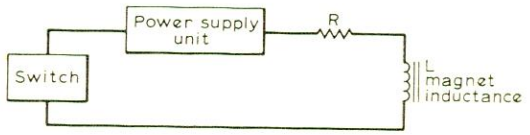


Fig 5.29. Simple teleprinter loop.

When the switch in this circuit is closed the current in the loop does not build up instantaneously. The current reaches about 62 per cent of its final value in L/R. Thus if the switch was a high speed keying relay the current in the loop would appear as shown in **Fig 5.30**.

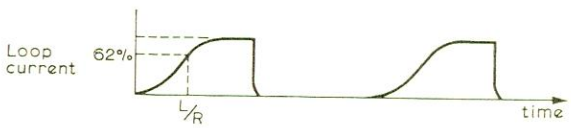


Fig 5.30. Loop current in the simple teleprinter loop.

As the inductance of a teleprinter magnet is fixed, then in order to get a fast rise time it is necessary to use a high value of R together with an increased voltage to keep the final loop current the same. However, polar relays are not easy to adjust and their action tends to generate rf hash in the receiver. A valve or transistor switch may be used instead. The electronic switch may be a pentode driven into hard conduction, a bipolar transistor driven into saturation, a unipolar transistor driven into the ohmic region, or a vacuum triode. In these cases the waveform will be almost the same as that obtained with a polar relay.

Fig 5.31. Loop current waveform for a typical pentode switched loop.

A pentode vacuum tube operated in a constant current mode as a magnet driver presents a more complex situation. The "pentode" term includes any device having pentode-like characteristics. Bipolar and unipolar transistors when operated in the constant current mode qualify but may not be practical because of their ratings.

Consider a pentode switch with the bias set to give a loop current equivalent to a mark signal. The resistance in the loop including the selector magnet resistance and excluding the dc anode resistance of the pentode should be as low as possible. (This is for pentodes only.) The loop current in such a system will be as shown in **Fig. 5.31**.

The rise time is linear and very fast. Hence the bias is very low. This represents an almost ideal situation.

It may have been noticed that selector magnets seem to flip back and forwards from mark to space quite merrily with only ± 6V applied, so the question is raised—why not use a 12V transistor driver? The system is shown in **Fig 5.32**,

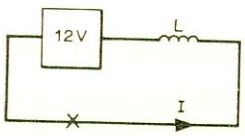


Fig 5.32. Low-voltage transistor switched loop.

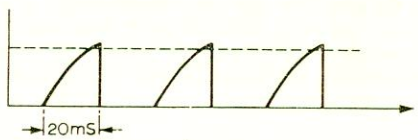


Fig 5.33. Loop current in low-voltage drop.

where X represents the collector-emitter "junction" of a bipolar transistor.

The loop current waveforms will appear as **Fig 5.33**.

The time constant of this circuit is relatively long. The current rises so slowly that it never reaches a steady state during a hypothetical mark interval. However, if three marks are sent in succession the steady state mark current will have

been reached by the end of the second or third mark. This will result in characteristic distortion as those letters with rapid reversals will not reach a steady state while those with few reversals will. The decision point, the current at which the magnet will flip from space to mark, is delayed to about 60 per cent of the total element length. This will result in 60 per cent bias of the signal and is unacceptable to the teleprinter that will only accept at most 50 per cent bias without misprinting. If however, a high voltage transistor such as a 2N3440 is used, the rise time will then be sufficiently fast to reduce the bias to a much lower level than will be acceptable to the teleprinter, **Fig 5.34**.

A transistorized driver and keyer appears in Chapter 6.

The following valve-operated polar relay circuit is useful in the case of an auxiliary demodulator being placed in an existing loop, **Fig 5.35**.

The polar relay is connected in the anode circuit of the 12AU7 with the ht feed to the slider of the wire wound 5kΩ potentiometer. This permits balancing of the anode currents of the triodes and so balances the polar relay. The contacts of the polar relay are connected to the local loop via a reversing switch. A simple filter is placed across the relay contacts to suppress any rf hash.

Between the "on" and "off" situations in a vacuum tube switch there exists a partially conducting state. An electronic switch that can be either "on" or "off" is usually placed just before the keyer tube so that the keyer tube never assumes the partially conducting state. Such an electronic switch is the Schmitt trigger circuit. For any voltage input below its decision level the trigger will be "off", for any voltage above this level the circuit will deliver a constant dc output. The circuit in **Fig 5.36** shows how the trigger is wired into the keyer.

$R_1C_1R_3$ form a low-pass filter. VR_2 is used to adjust the decision point of the trigger tube. VR_1 controls the current flowing through the NE51. When the neon strikes, a positive voltage overcomes the bias on the 6W6 and the keyer tube conducts.

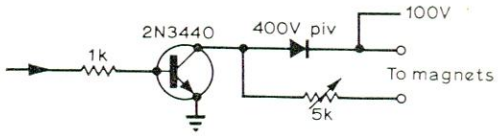


Fig 5.34. A high-voltage transistor keyer stage showing back emf protection diode.

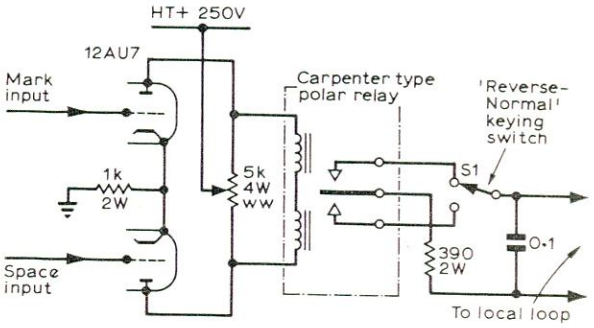


Fig 5.35. Valve-operated polar relay.

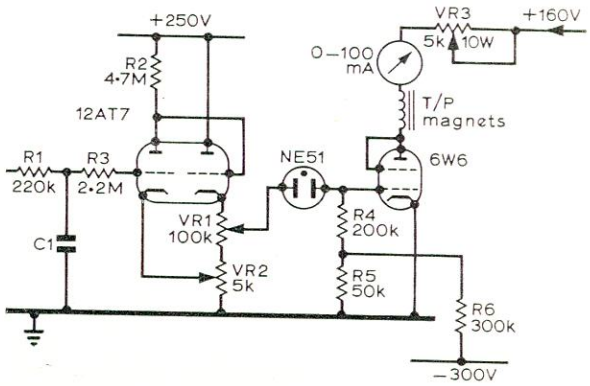


Fig 5.36. Keyer circuit with trigger. Adjustment of VR1 and VR2 is explained in the test.

RADIO INTERFERENCE IN LOOPS

Since the relatively high current in the loop is broken suddenly quite a hash may be picked up on a nearby receiver. This is much more evident in loops containing polar relays. The solution here is to use screened wire to connect the demodulator to the teleprinter and to avoid an earth loop between the machine and the demodulator. A small LC filter across the relay contacts may help but any filters containing inductance should be examined warily as the loop time constant characteristics may be adversely affected.

W2PAT RECEIVING CONVERTER

The circuit shown in **Fig 5.37** is a modified version of the W2PAT TU, a unit popular in the early days of rtty and reproduced here as it combines some of the principles already discussed. The input transformer, with the higher resistance winding connected into the grid circuit of the first valve and its loudspeaker winding connected to the low resistance output terminals of the receiver, can be a normal valve output transformer.

The first valve is connected as a limiter, and the limited output is fed to the two tuned circuits L1C1, L2C2 which are resonated at 2125 and 2975Hz, via the 50kΩ potentiometer and the 47kΩ resistors. The tuned circuits are connected to the grid circuits of the second valve which functions as a detector and the resulting outputs are coupled through N1 and N2 to the keyer valve V_3, which has a polar relay connected between the cathodes. N_1 and N_2 may be any low-striking voltage neons.

The power supply requirements are 250V at 30mA ht and 6·3V at 0·9A lt.

The potentiometer VR1 should be set to give zero reading on the meter with no signal. On applying the signal and varying the receiver bfo, first one and then the other neon should light up temporarily. By adjusting the bfo, the neons should then flash in step with the fsk signal and the relay should follow in step.

THE DL6EQ TWO-TONE LIMITERLESS DEMODULATOR

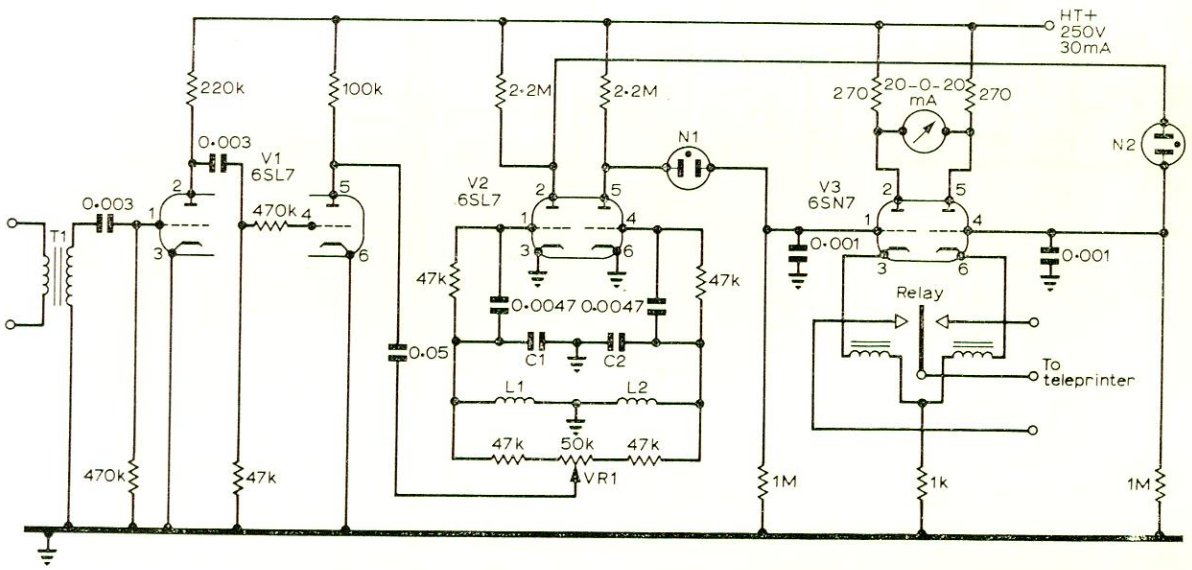
The limiter-discriminator type of converter performs exceedingly well when there is a fair signal to noise ratio and the levels of the mark and space signals are approximately equal at the receiver. However, when selective fading occurs, it produces a continuous variation in the relative levels of both signals. This incorrect relationship between the levels in the mark and space channels results in a keying bias. However, a type of detector has been designed, the "slideback detector", in which the output of each channel is combined immediately before some form of keying circuit, this latter determining whether the signal was to be a mark or space. The slideback detector is, in fact, two detectors, one being used to develop the normal keying waveform and the other, possessing a relatively long time-constant, determines the amount of signal energy present. The two types of information are combined to produce a signal which is symmetrically arranged about the zero voltage reference line. This signal is combined with the output from the other channel—which should be an inverted image of the first channel if both mark and space signals are present. The net result is that there is then a system which will key the teleprinter perfectly well when there is a radical difference in the levels of the mark and space signals at the receiver input. Where both signals are strong, the output from the two channels merely reinforce each other.

The first valve in the circuit is a straight audio amplifier and it is important that these two stages are not overloaded by too high an input voltage since this will produce limiting and destroy the whole action of the circuit. After amplification, the signal is passed to the input of the two-tone discriminators via C3 and the potentiometer VR1, which is adjustable to compensate for differences in the input levels to the two channels. It is a linear type of control and can be mounted on the front panel as a balance control. The tone discriminators separate the two tones and these signals are then passed via a dpdt switch to their respective detector circuits. The function of this switch is the usual reverse/normal keying control found on most demodulators. The output of the two detectors is combined at point M3 and passed to V5, which is the decision stage. This is a Schmitt Trigger circuit, in which C10, R21 and R23 form a low-pass filter network to improve the keying waveform. The trigger circuit is adjusted to change its state at either side of zero grid voltage. The potentiometer VR3 is used for this adjustment. VR2 controls the level of drive voltage applied to the two NE51 neons and is used to adjust the current through them. (Excessive current will rapidly burn them out and too little will cause them to trigger erratically.) A slightly negative voltage applied to the grid of the first half of V5 will produce a positive voltage of something like 120V on the cathode of the second half. This will strike the neons which will then pass the voltage to the grids of V3 and V4. The latter are biased back by a negative voltage derived from the grid bias supply via the potential divider R2/R4. The positive signal voltage drives both valves to a high anode current point, thus producing a mark signal in the winding of the teleprinter electromagnet, which is in their anode circuit.

An extra to the demodulator is a magic eye tuning indicator. This uses an EM M801 which has two separate displays, one to monitor the space channel and one for the mark channel.

The power supplies for the unit are quite modest: the demodulator proper requires 250–300V dc at about 15mA. The keyer stages require 40mA or so at about 100–110V. The grid bias supply to the keyer stage may be anything from 150–350V, the values of R2 and R4 being adjusted to

Fig 5.37. W2PAT terminal unit.



suit the bias voltage available. (The values given are for a 300V supply.)

The demodulator is adjusted in the following stages:

1. Temporarily strap the top of the resistor R23 shown on the diagram to earth.
2. Adjust the slider of VR2 to about one third of its travel away from the cathode.
3. Set the slider of VR3 at the bottom (earthy) end of its track.
4. Gradually move the slider of VR3 up from the earthy end until a point is reached at which the two neons strike: note this setting carefully.
5. Return the slider of VR3 gradually towards the earthy end until the neons are extinguished. The correct setting is midway between these two points.
6. Remove the temporary strap from R23 and apply a small negative voltage between this point and earth. This should be no more than $-1\frac{1}{2}$V and should cause the neons to trigger at once. The neons should be glowing with moderate brightness but if not the neon current should be adjusted by varying the potentiometer VR2.

If any adjustment is necessary then the steps 1 to 5 must be repeated: if not, remove the $1\frac{1}{2}$V test voltage.

The adjustment of the controls VR2 and VR3 interlock but it should only be necessary to repeat the steps 1 to 5 once. The demodulator is then ready for business.

A reduction in both noise and interference can be brought about by the addition of a bandpass filter in the region of 2–3kHz ahead of the demodulator input. The correct voltage input is in the region of 0·2V.

A SIMPLE TRANSISTORIZED TERMINAL UNIT (Fig 5.39)

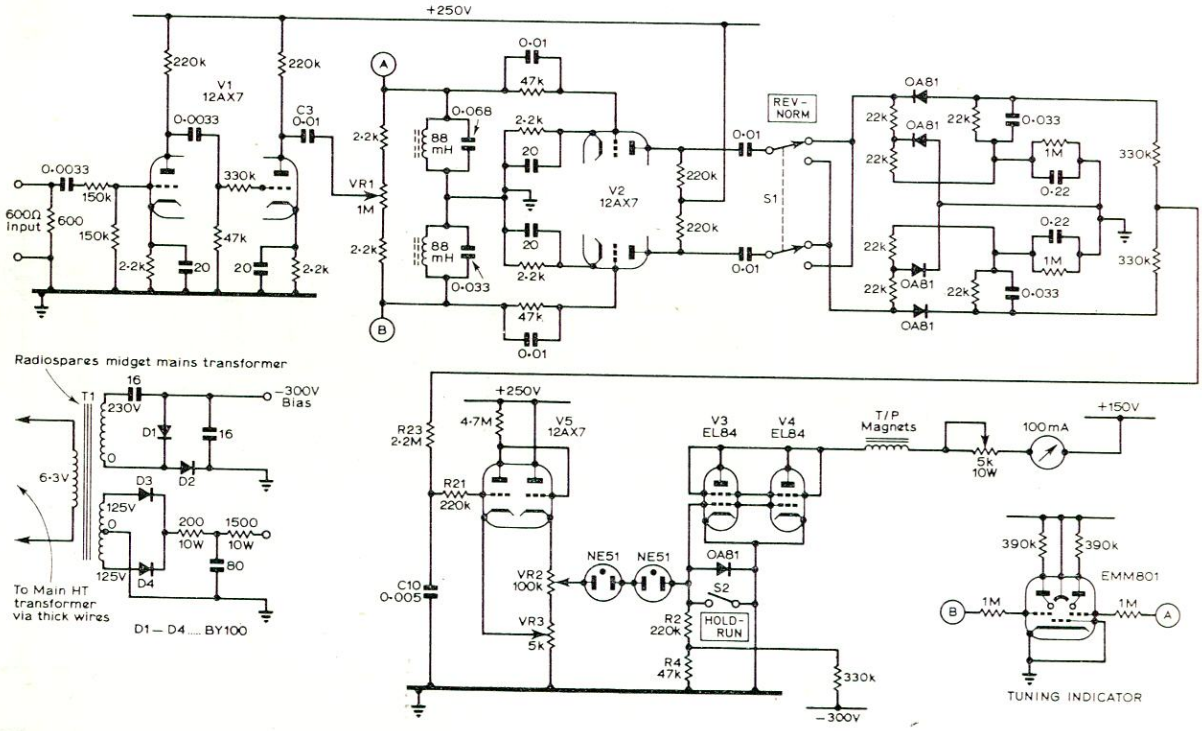
This design does not have a polar relay output but instead uses a high voltage transistor to key the loop. If polar operation is required, however, the 2N3440 may be changed to a 2N1304, 2N708, etc and the double current magnet driver in Chapter 6 may be connected.

The input to the toroids is direct from the receiver 3Ω output via link couplings. These are nine turns for the mark and four turns for the space coils, wound in the same direction as the toroid.

0·066μF and 0·033μF should tune the toroids to the mark and space frequencies. The low voltage neons are tuning indicators. The receiver should be tuned for maximum brilliance of both neons. The first two transistors are used as a Schmidt Trigger to ensure a good square waveform for the keying stages. The 2N1304 has an emitter follower to isolate the keyer from the trigger. The 2N3440 that keys the teleprinter loop is a high voltage transistor and the collector resistor should be 2kΩ for a 100V loop and 3kΩ for a 150V loop.

The dpdt switch is the usual "normal-reverse" switch to copy signals that use 2,975Hz for mark instead of 2,125Hz.

Fig 5.38. Circuit diagram of the DL6EQ two-tone limiterless demodulator.



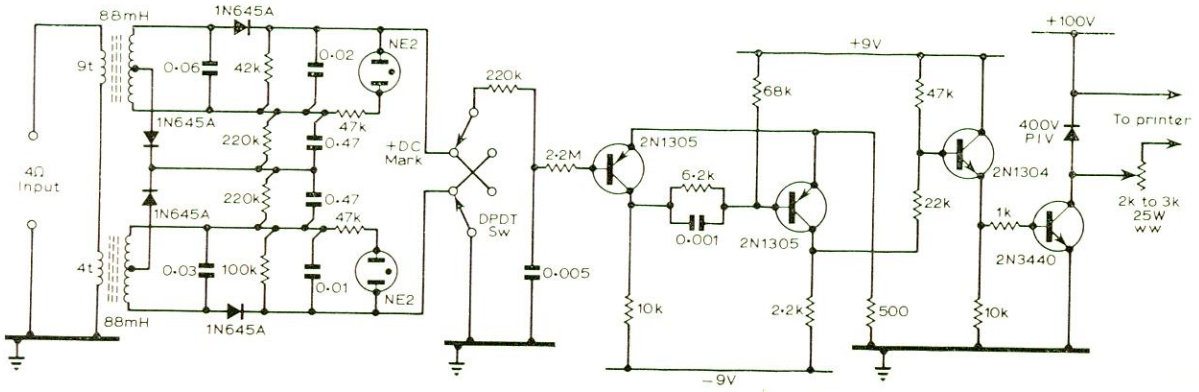


Fig 5.39. The circuit diagram of a simple transistorized terminal unit

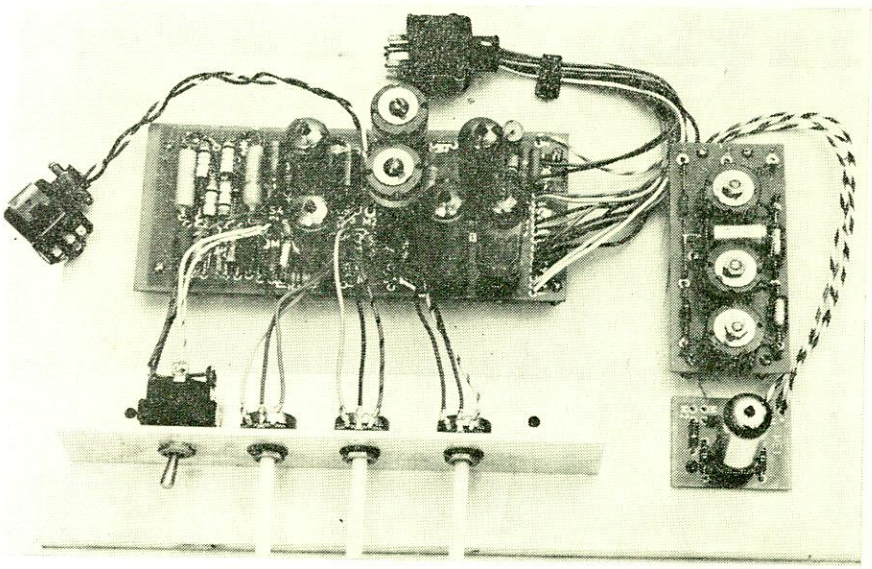
THE MAINLINE TT/L-2 FSK DEMODULATOR (Fig 5.40, inset)

The introduction of the TT/L terminal unit has probably been the most significant development in amateur rtty in recent years. Because of the importance of some of the technical features used in this design and their application to other designs covered later in this chapter, the circuit will be discussed in some detail.

The Mainline TT/L was originally published in *RTTY Journal* in November 1964 and was the result of nearly a year's work in design by Keith Petersen, W8SDZ, Irvin M. Hoff, K8DKC (now W6FFC), and Victor Poor, K3NIO. An improved version was published in August 1965 *QST*, and a still further developed version, the TT/L-2, appeared in *RTTY Journal*, September 1967.

General Description

The Mainline TT/L-2 is an advanced design fsk demodulator offering high performance fm (limiter) and a.m. (limiterless) reception of radio teleprinter signals. The design includes both the decision threshold computer and automatic threshold corrector circuits that automatically control the incoming signal in a manner that allows mark, space or both to provide normal reception. The unit has a dynamic range of approximately 60dB which allows the reception of deeply fading signals. Reception of either 850Hz or 170Hz signals is provided by two separate bandpass input filters and linear discriminators. A special symmetrical limiter provides more than 60dB of "zero time constant" limiting. It also gives complete freedom from frequency doubling. An extremely effective and accurate tuning indicator which directly compares the amplitudes of the mark and space signals is included. Also included is a unique auto-receive (squelch) circuit which prevents the receiving teleprinter



A demonstration model DL6EQ terminal unit.

from printing garble when there is no signal present. This circuit is so designed as to ignore completely cw and other non-rtty signals that may be within the received passband. The auto-receive circuit also controls a simple one valve motor control which turns off the teleprinter motor 30–45s after the signal leaves. This delay is sufficient to keep the motor turned on during station cw identification and subsequent turn-over to the other station. The combination of the auto-receive and the motor control stages provides an efficient and reliable autostart system for the unattended reception of rtty signals.

A newly developed anti-space circuit keeps the printer from "running wild" and prevents the auto-receive circuit from responding to steady space signals. Provision is made for reception of higher teleprinter speeds by the inclusion of a switchable three-speed low-pass filter. Mode switching is extremely simple and straightforward allowing full control of all functions while avoiding possible wrong combinations. This is done by grouping four different functions on one rotary switch.

The loop supply is of heavy duty low hum design. It provides balanced voltage output for direct drive of a saturated-diode fsk or afsk circuit. It also features automatic retransmission of received signals, such as relaying from another band or playback from a tape recorded signal.

The main power supply is of heavy duty design to provide reliable continuous operation. Voltage regulation is provided for critical circuits so that the unit will operate normally with ac mains voltages between 200–250V.

Circuit Description

Two bandpass filters are provided. These filters are three-pole Butterworth design and utilize the commonly available 88mH toroids. The use of these toroids in the design necessitated a higher impedance than normal but this is advantageous in that when simple resistor impedance matching is used, a decoupling action takes place which isolates the filters from any reactance in the receiver output circuit, and at the same time provides a constant load for this output circuit. The bandwidth of the filter for 170Hz shift is approximately 275Hz, and that of the 850Hz shift filter is approximately 1,000Hz.

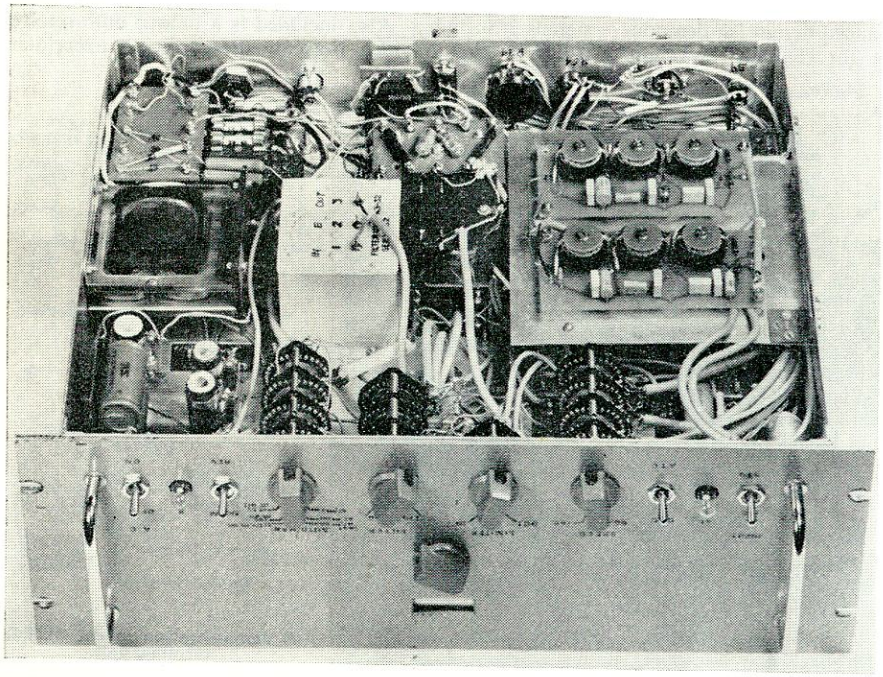
Amplifier Stage

This stage amplifies the output of the bandpass input filter and is transformer-coupled to either the first limiter input or directly to the discriminator, depending on the position of the limiter by-pass switch. Transformer-coupling is used for two reasons: (1) It provides the necessary impedance matching and voltage step-up between the plate of the amplifier stage and the grid circuit of the first limiter; (2) It provides a "zero time constant" drive for the first limiter grid circuit.

Limiter Stage

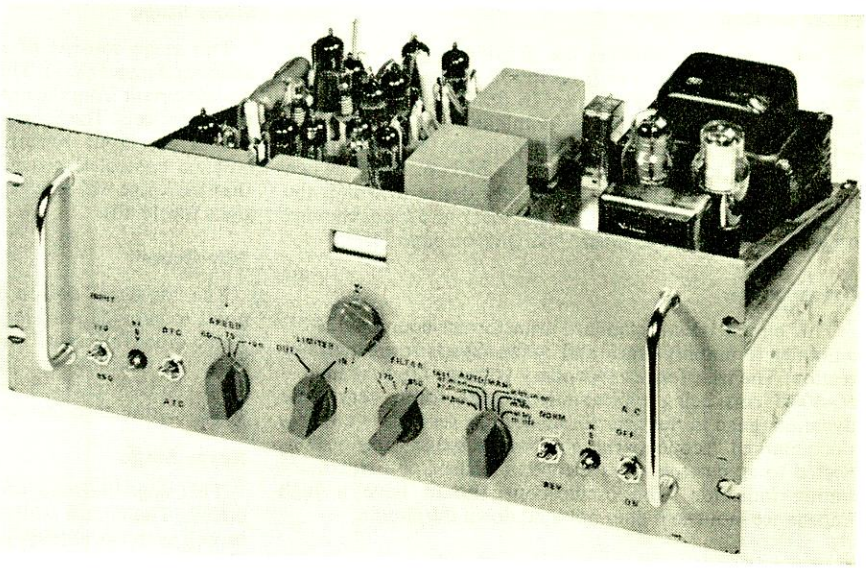
Limiting is provided by two 6BN6 valves in cascade. Both stages are transformer-driven to provide more than 60dB of "zero time constant" limiting. The 6BN6 is said to be one of the finest fm limiters available today. It provides "symmetrical limiting" which eliminates the possibility of frequency doubling and also provides much improved limiter performance compared to older types of limiters.

The in-out switch is provided to bypass the limiters when limiterless (a.m.) copy is desired. This method of switching from fm to a.m. reception eliminates the need for separate input stages for each mode.

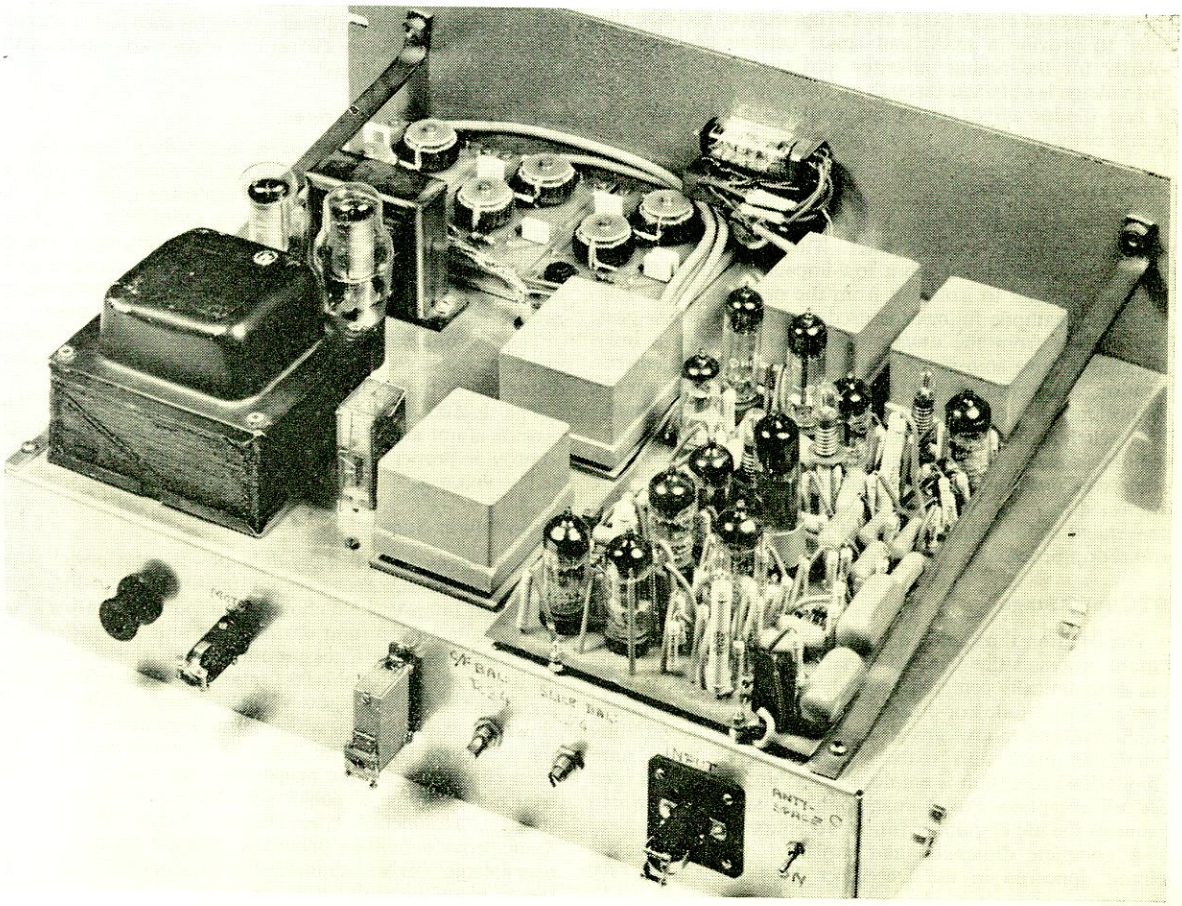


A version of the TT/L-2 fsk demodulator built by G8LT.

The G8LT version of the TT/L-2 showing the front panel layout.



Interior view of the TT/L-2 as built by G8LT.



Filter Section

Two linear discriminators are provided—one for 850Hz shift and one for 170Hz shift reception. Any shift from 4Hz to cover 1,000Hz may be received by utilization of "straddle-tuning". No retuning of the discriminator is required.

Commonly-available 88mH toroids are used for best stability and freedom from inductive pickup. Extra switch positions are available should the user desire to install the narrow-band three-pole Butterworth mark and space channel filters described in September 1966 *QST* on page 34.

Driver Stage

This circuit uses a standard transformer-coupled 12AT7 amplifier to amplify mark and space signals from the filter section. The transformer secondary voltages are very high—50–100V rms being typical—to provide for a very wide dynamic range in the detector stage. The secondary connections marked "scope mark" and "scope space" may be connected to an external oscilloscope to be used as an auxiliary tuning indicator. The oscilloscope should have a high impedance input so it does not load down the circuit.

Detector Stage

This stage uses two standard parallel-combined detectors. The polarities of one detector are the opposite of the other in order to provide a mark and space voltage of identical polarity for the tuning indicator and auto-receive stages. This voltage is obtained through an "or gate" which consists of two diodes wired across the contacts of the normal-reverse switch.

Low-pass Filter Stage

This stage consists of two cathode followers and a three-pole Butterworth low-pass filter. The left-hand cathode follower is used to provide a low-impedance drive source for the filter and to isolate it from the detector stage. The right-hand cathode follower is used to isolate the low-pass filter output from the dtc/atc stage and provides a low-impedance drive source for that stage. A four-pole, three-position rotary switch is used to select the proper components for optimum cut-off frequency to 60, 75 or 100 wpm signals. This switch is shown in the 60 wpm position on the diagram. It is thus clearly seen which components associated with the other two positions may be omitted if the builder is not interested in 75 or 100 wpm. The test point is provided for convenient connection of a meter for use during the balance and set-up procedure.

DTC/ATC Stage

The decision threshold computer and threshold corrector circuit processes the detected signal so that mark and space are automatically centered around "zero". The effect is to correct for mistuned or drifting signals when fm reception is employed, and to give proper decision level to the variable-amplitude mark and space signals received when a.m. (limiterless) reception is employed. The dtc position is used for all reception except mark-only or space-only which requires the atc circuit for proper reception.

A complete discussion and explanation of the dtc/atc circuit appeared in the December 1964 issue of *RTTY Journal*.

Slicer Stage

This stage consists of a cathode follower (V-6A) and a Schmidt Trigger (V-7). The cathode follower is to isolate the dtc/atc circuit from the input of the Schmidt Trigger to avoid loading effects. The Schmidt Trigger is a standard type which proves an input sensitivity of approximately 30mV. A balance control is provided to adjust the cathode bias so that the valve will trigger properly. See adjustment instructions for details.

"Or Gates"

The "or gates" consist of three diodes wired to a common point to provide marking voltages to the 6W6 keyer stage. These diodes prevent "backing-up" of the positive voltages from the three circuits that drive this common point. The 6W6 receives marking voltages from either: (1) the slicer stage, (2) the auto-receive stage, or (3) the anti-space stage.

Keyer Stage

This stage utilizes a triode-connected 6W6 to key the loop circuit. The circuit is designed so that the incoming signal, as well as the local teleprinter, can key the fsk voltage output. This allows the operator to re-transmit any incoming signal from another band or from a tape recorder. From this it can be seen that the user must open the external standby switch while he is transmitting so that his own signal will not feed back into the loop. Of course, when retransmitting the switch must remain closed.

Loop Supply and fsk Driver

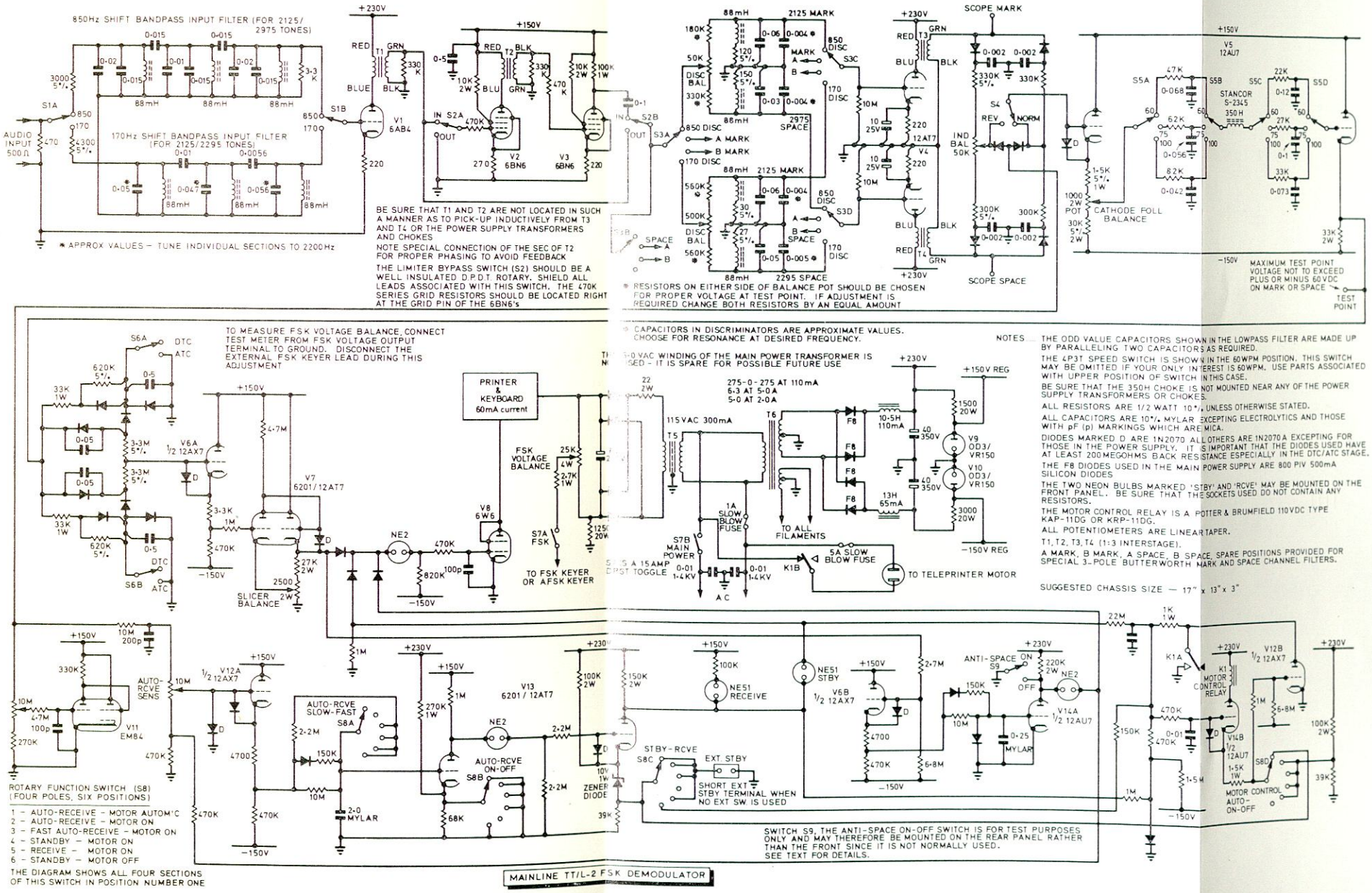
The loop supply utilizes a heavy-duty line-isolation transformer and bridge rectification for excellent regulation and low hum level. The printer, keyboard and other teleprinter equipment are connected in series with the 60mA loop. This allows normal operation of all equipment. Direct-drive of a saturated-diode fsk and afsk circuit is provided by sampling the loop signal through a simple resistor bridge circuit. The system is all-electronic—no relays are used.

The fsk voltage balance control is provided to allow adjustment for exactly equal mark and space voltages to prevent distortion of the transmitted signal.

The 1,250Ω 20W resistor sets the loop current. This resistor is not adjustable because its value has been chosen to provide proper operation of the loop circuit with varying ac line voltages.

Main Power Supply

This supply uses a heavy-duty power transformer which is rated by the manufacturer for 110mA with a capacitor-input filter, and 140mA with a choke-input filter. This rating is well above the actual current drain of the unit and provides for very cool operation. Choke-input filtering is used in both the positive and negative circuits for best regulation. The ±150V regulators are both OD3/VR–150 valves. This type was chosen because it has a wider regulating current range than the miniature OA2. The VR-tube dropping resistors have been chosen to provide proper operation of the regulators over a wide range of power line voltages. The rectifiers are special "avalanche" type 800piv 500mA silicon diodes. They provide built-in protection against reverse transient overvoltage spikes. Large filter capacitors are used to give low hum and good dynamic regulation.


850Hz SHIFT BANDPASS INPUT FILTER (FOR 2125/2975 TONES)
170Hz SHIFT BANDPASS INPUT FILTER (FOR 2125/2295 TONES)
AUDIO INPUT 500Ω
S1A
S1B
V1 6AB4
+230V
+150V
V2 6BN6
V3 6BN6
S2A
S2B
S3A
S3B
S3C
S3D
2125 MARK
2975 SPACE
2295 SPACE
MARK
SPACE
850 DISC
170 DISC
DISC BAL
V4 12AT7
SCOPE MARK
SCOPE SPACE
S4
REV
NORM
IND BAL 50K
CATHODE FOLL BALANCE
V5 12AU7
S5A
S5B
S5C
S5D
STANCOR S-2345
350 H
MAXIMUM TEST POINT VOLTAGE NOT TO EXCEED PLUS OR MINUS 60 VDC ON MARK OR SPACE
TEST POINT
* APPROX VALUES – TUNE INDIVIDUAL SECTIONS TO 2200Hz
BE SURE THAT T1 AND T2 ARE NOT LOCATED IN SUCH A MANNER AS TO PICK-UP INDUCTIVELY FROM T3 AND T4 OR THE POWER SUPPLY TRANSFORMERS AND CHOKES
NOTE SPECIAL CONNECTION OF THE SEC OF T2 FOR PROPER PHASING TO AVOID FEEDBACK
THE LIMITER BYPASS SWITCH (S2) SHOULD BE A WELL INSULATED D.P.D.T. ROTARY. SHIELD ALL LEADS ASSOCIATED WITH THIS SWITCH. THE 470K SERIES GRID RESISTORS SHOULD BE LOCATED RIGHT AT THE GRID PIN OF THE 6BN6's
* RESISTORS ON EITHER SIDE OF BALANCE POT SHOULD BE CHOSEN FOR PROPER VOLTAGE AT TEST POINT. IF ADJUSTMENT IS REQUIRED CHANGE BOTH RESISTORS BY AN EQUAL AMOUNT
TO MEASURE FSK VOLTAGE BALANCE, CONNECT TEST METER FROM FSK VOLTAGE OUTPUT TERMINAL TO GROUND. DISCONNECT THE EXTERNAL FSK KEYER LEAD DURING THIS ADJUSTMENT
S6A
S6B
DTC
ATC
V6A 1/2 12AX7
V7 6201/12AT7
SLICER BALANCE
FSK VOLTAGE BALANCE
S7A FSK
TO FSK KEYER OR AFSK KEYER
PRINTER & KEYBOARD 60mA current
NE2
V8 6W6
S7B MAIN POWER
5A 15AMP DPST TOGGLE
1A SLOW BLOW FUSE
TO ALL FILAMENTS
5A SLOW BLOW FUSE
K1B
TO TELEPRINTER MOTOR
AC
115 VAC 300mA
T5
T6
275-0-275 AT 110mA
6.3 AT 5.0A
5.0 AT 2.0A
10·5H 110mA
13H 65mA
F8
V9 OD3/VR150
V10 OD3/VR150
+150V REG
–150V REG
ROTARY FUNCTION SWITCH (S8) (FOUR POLES, SIX POSITIONS)
1 – AUTO-RECEIVE – MOTOR AUTOMATIC
2 – AUTO-RECEIVE – MOTOR ON
3 – FAST AUTO-RECEIVE – MOTOR ON
4 – STANDBY – MOTOR ON
5 – RECEIVE – MOTOR ON
6 – STANDBY – MOTOR OFF
THE DIAGRAM SHOWS ALL FOUR SECTIONS OF THIS SWITCH IN POSITION NUMBER ONE
V11 EM84
V12A 1/2 12AX7
V12B 1/2 12AX7
V13 6201/12AT7
V14A 1/2 12AU7
V14B 1/2 12AU7
AUTO-RCVE SENS
AUTO-RCVE SLOW-FAST
S8A
AUTO-RCVE ON-OFF
S8B
STBY-RCVE
S8C
EXT STBY
SHORT EXT STBY TERMINAL WHEN NO EXT SW IS USED
NE51 RECEIVE
NE51 STBY
V6B 1/2 12AX7
ANTI-SPACE ON
S9
OFF
SWITCH S9, THE ANTI-SPACE ON-OFF SWITCH IS FOR TEST PURPOSES ONLY AND MAY THEREFORE BE MOUNTED ON THE REAR PANEL RATHER THAN THE FRONT SINCE IT IS NOT NORMALLY USED. SEE TEXT FOR DETAILS.
K1A
K1 MOTOR CONTROL RELAY
S8D
MOTOR CONTROL AUTO-ON-OFF
ZENER DIODE
MYLAR
MAINLINE TT/L-2 FSK DEMODULATOR

* CAPACITORS IN DISCRIMINATORS ARE APPROXIMATE VALUES. CHOOSE FOR RESONANCE AT DESIRED FREQUENCY.

-0 VAC WINDING OF THE MAIN POWER TRANSFORMER IS SED – IT IS SPARE FOR POSSIBLE FUTURE USE

NOTES — THE ODD VALUE CAPACITORS SHOWN IN THE LOWPASS FILTER ARE MADE UP BY PARALLELING TWO CAPACITORS AS REQUIRED.

THE 4P3T SPEED SWITCH IS SHOWN IN THE 60WPM POSITION. THIS SWITCH MAY BE OMITTED IF YOUR ONLY INTEREST IS 60WPM. USE PARTS ASSOCIATED WITH UPPER POSITION OF SWITCH IN THIS CASE.

BE SURE THAT THE 350H CHOKE IS NOT MOUNTED NEAR ANY OF THE POWER SUPPLY TRANSFORMERS OR CHOKES.

ALL RESISTORS ARE 1/2 WATT 10%, UNLESS OTHERWISE STATED.

ALL CAPACITORS ARE 10% MYLAR EXCEPTING ELECTROLYTICS AND THOSE WITH pF (p) MARKINGS WHICH ARE MICA.

DIODES MARKED D ARE 1N2070 ALL OTHERS ARE 1N2070A EXCEPTING FOR THOSE IN THE POWER SUPPLY. IT IS IMPORTANT THAT THE DIODES USED HAVE AT LEAST 200 MEGOHMS BACK RESISTANCE ESPECIALLY IN THE DTC/ATC STAGE.

THE F8 DIODES USED IN THE MAIN POWER SUPPLY ARE 800 PIV 500mA SILICON DIODES

THE TWO NEON BULBS MARKED 'STBY' AND 'RCVE' MAY BE MOUNTED ON THE FRONT PANEL. BE SURE THAT THE SOCKETS USED DO NOT CONTAIN ANY RESISTORS.

THE MOTOR CONTROL RELAY IS A POTTER & BRUMFIELD 110VDC TYPE KAP-11DG OR KRP-11DG.

ALL POTENTIOMETERS ARE LINEAR TAPER.

T1, T2, T3, T4 (1:3 INTERSTAGE).

A MARK, B MARK, A SPACE, B SPACE, SPARE POSITIONS PROVIDED FOR SPECIAL 3-POLE BUTTERWORTH MARK AND SPACE CHANNEL FILTERS.

SUGGESTED CHASSIS SIZE — 17" x 13" x 3"

Fig 5.40. The circuit diagram of the Mainline TT/L-2 fsk demodulator.

Tuning Indicator

This stage uses an EM84/6FG6 single-bar tuning eye. The circuit is arranged so that both mark and space close the eye equally when the signal is tuned in correctly. The indicator sensitivity potentiometer is provided so that the user may control the amount of eye closure to suit his preference. The best setting is one where the eye just closes. If the signal drifts the eye immediately starts to open, signalling the operator to retune.

The ht source for this tube is 150V regulated. This provides two advantages:

1. Freedom from variations in the amount of eye closure due to the line voltage variations.
2. Increased fluorescent target life due to the lower-than-normal voltage. The brightness is more than adequate for operation in a normally lighted room.

Auto-receive Stage

This stage consists of:

1. A cathode follower.
2. An R–C time constant network.
3. A dc amplifier/neon trigger.
4. A second dc amplifier/neon coupler.

The cathode follower is used to isolate the R–C time constant network from the high-impedance source of signal voltage. The grid has a diode clamp to prevent it from going positive.

The R–C time constant network is arranged to have slow-attack and fast-release. This prevents cw and other non-rtty signals from fully charging the capacitor.

The first dc amplifier is used to control the triggering neon in its plate circuit. The gain of this stage provides for exceptionally sensitive triggering action. This allows the circuit to distinguish easily between the dc levels of signal and noise.

The second dc amplifier is used to control the neon coupler which feeds into the "or gate" to provide an artificial marking voltage for the 6W6 keyer valve when there is no signal. This amplifier's cathode bias is stabilized with a zener diode so that its keying point will always be the same with varying line voltages. When the standby switch is opened, the cathode circuit is biased heavily positive, causing this valve to be cut off. This allows the neon coupler to fire, applying a marking voltage to the 6W6 keyer.

The auto-receive circuit was designed to be used only when receiving in the fm (limiter) mode. When the a.m. (limiterless) mode is used, the function switch (S-8) should always be in the number 5 position.

Anti-space Stage

This stage consists of:

1. A cathode follower (V-6B).
2. An R–C time constant network.
3. A dc amplifier/neon trigger.

The cathode follower (V-6B) is used to provide isolation from the slicer stage and to give a low impedance source for the R–C constant network.

The R–C time constant network is arranged to have slow-attack and release. This allows it to distinguish between normal teleprinter signals and steady space signals.

The dc amplifier (V–14A) is used to control the neon trigger which feeds a positive voltage into the "or gate" to provide an artificial marking signal for the 6W6 keyer valve when a steady space signal is received. The neon trigger also applies a positive voltage to the grid of the auto-receive cathode follower (V–12A), causing the diode clamp to saturate. This effectively grounds the auto-receive stage input and makes that stage operate as if no signal was being received. Thus it can be seen that steady space signals are rejected entirely.

Motor Control Stage (V-14B 7 V-12B)

This stage consists of:

1. A dc amplifier (V–14B) to operate the motor control relay.
2. A timing network consisting of an R–C time constant network and a neon trigger.
3. A clamp valve (V–12B).

The dc amplifier is directly controlled by the auto-receive stage so that when a signal is received the teleprinter motor is turned on. When the signal leaves, the motor remains turned on. The artificial marking voltage which is applied to the "or gate" by the auto-receive stage is also applied to the R–C time constant network and neon trigger. When the charge on the capacitor builds up sufficiently the neon fires—turning off the motor.

The clamp tube (V–12B) is actuated during "standby" and "motor on" modes of operation to prevent triggering of the neon. It does this by discharging the time constant capacitor.

The motor control stage works only when the auto-receive circuit is in operation.

The ac line voltage for the teleprinter is obtained from the main power switch so that the machine will be turned off when the TT/L–2 is off.

Adjustment Instructions

Allow the unit to warm up for at least 15min before any adjustments are made. The valves will age during the first few days of operation so it is wise to repeat the entire adjustment procedure about a week after initial set-up.

These adjustments should always be done in the order shown below or improper operation will result.

1. Cathode Follower Balance

This is the first adjustment to be made. Connect a sensitive voltmeter or valve voltmeter to the test point. Remove all audio input to the TT/L–2 by unplugging the input cable. Set the limiter bypass switch to the out position. Adjust the cathode follower balance potentiometer for zero voltage at the test point.

2. Slicer Balance

This adjustment is also made with no audio input and the limiter bypassed. The anti-space switch (S–9) should be set to the "off" position for this adjustment.

Turn the slicer balance potentiometer until the teleprinter "runs open". Turn the potentiometer in the opposite direction until the printer returns to marking. Note these two points and set the potentiometer mid-way between them. No further adjustment is necessary. Return the anti-space switch to the "on" position.

3. Filter Stage

The discriminators should be tuned to the desired tone frequencies by varying the capacitors marked with asterisks. During the tuning procedure, the resistors in series with the ground connection of the toroids should be temporarily shorted out. Be sure to remove these shorts after the tuning is completed or severe distortion of the received teleprinter signals will result.

The resistors marked with asterisks on either side of the balance potentiometer should be chosen so that the mark and space voltages, when balanced, do not exceed ±60V at the test point. If it becomes necessary to change the value of these resistors, be sure to change them both an equal percentage so as to maintain a balance within the range of the potentiometer.

Adjustment of the discriminator or balance potentiometer is made with the limiter bypass switch set to the "in" position and the normal-reverse switch set to the "normal" position.

Apply alternately a mark and space signal to the input of the TT/L-2. Adjust the discriminator balance potentiometer so that the mark and space voltages are equal, but of opposite polarity, at the test point.

4. Indicator Balance

After the discriminators have been balanced, set the normal-reverse switch to the "reverse" position and adjust the indicator balance potentiometer for equal mark and space voltages at the test point.

Observe the tuning eye. If there is any movement when alternating the mark and space, carefully adjust the indicator balance potentiometer to eliminate it. No further adjustment is necessary.

5. FSK Balance

Set the rotary function switch (S–8) to positive 4 (standby). Alternatively open and close the loop by pushing the "break key" or opening the keyboard contacts of the teleprinter. Adjust the fsk voltage balance potentiometer for equal, but opposite, mark and space voltages. Mark should be approximately −45V and space should be approximately +45V. No further adjustment is necessary.

6. Auto-receive Sensitivity

It is best to use the receiver's 100kHz crystal calibrator or an actual signal for this adjustment. Set the rotary function switch (S–8) to position 2 (auto-receive motor on).

With no signal (just noise) input to the TT/L–2 adjust the auto-receive sensitivity potentiometer so that when a signal is applied there is a delay of 3–4s before the "rcve" neon indicator lights. If your adjustment is correct, the teleprinter should print five or six letters after the signal leaves and then remain quiet.

The proper audio input level for the TT/L–2 is that which produces the same amount of tuning-eye closure in either fm (limiter) or a.m. (limiterless) modes of operation. It will be found that this is slightly above normal room volume and it will be necessary to install a pad in the speaker circuit to bring its volume down to a suitable listening level. The pad offers two advantages:

1. It decouples the variable impedance of the speaker from the receiver output circuit.

2. It helps prevent pickup of room noise by the speaker which could couple into the TT/L–2 input and cause interference to the desired signal.

Construction Notes

The layout used for construction of the TT/L–2 should be similar to that used in a high-quality audio pre-amp. This is desirable because of the very high-gain circuitry used. Be sure to shield all audio and high-impedance dc leads which might pick up extraneous signals or noise due to physical length or placement.

The wiring associated with the grids of V–1, V–5A (left-hand section), V–6A and V–12A should be very short or shielded. All wiring associated with limiter bypass switch should be shielded.

It is most important that T–1 and T–2 transformers be mounted in such a way that they will not pick up inductively from each other, from T–3 and T–4, or from the power supply transformers and chokes. The best method to assure this is to mount T–1, T–2, T–3 and T–4 on different axes. Do not mount one above and one below the chassis in an effort to avoid inductive coupling because the usual aluminium chassis used will not provide inductive shielding.

All switches, except S–9, should be mounted on the front panel.

The auto-receive sensitivity and the indicator sensitivity potentiometer should be mounted on the front panel. All other potentiometers should be mounted on the rear panel.

The test point located at the cathode of V–5B (right-hand section) should be mounted in a convenient spot on or near the rear panel.

It will be observed that no power-on-indicator has been included in the design. It was purposely omitted because the tuning-eye provides this indication.

The "rcve" and "stby" neon indicators may be mounted on the front panel, if desired, to show when the unit is ready to receive a signal. If the builder does not wish to include these indicators, the "rcve" neon and its resistor may be omitted, but the "stby" neon must be retained as it is used for other purposes.

The rotary function switch (S–8) should be a shorting type, while the bandpass filter and limiter bypass switches should be of the non-shorting type.

To prevent cathode stripping after just switching on, the grids of V–5A, V–6A, V–6B, V–7B, V–8, V–12A, V–13B and V–14B should be clamped to their cathodes with a 1N2070A silicon diode. This prolongs the life of the valves.

If the first limiter plate transformer has a tendency to ring or if the limiters tend to oscillate when no signal is applied, a 0·002μF 600V capacitor should be connected across the primary leads of the transformer.

Voltage Readings

With a 1·5V peak to peak, 2,125Hz signal at the grid of V–1 there should be about 40V peak to peak at the anode, about 10V peak to peak at the grid of V–2, 45V peak to peak at the grid of V–3, 40V peak to peak at the centre of R–15 and the plate of V–4. There should be around 120V or so at the secondary of T–3.

DC voltages are present from this point on. Grid of V–6A is approximately 50V with the atc/dtc switch at dtc and about −28V at atc. All other voltages are with the switch at dtc. Cathode of V–6A −50V, grid of V–7A −45V, approxi-

mately. The grid of V–8 (6W6) should be about 0 to −0·2V with mark and −45–5V with space. Diode D–15 should have the same positive voltage on each side. The far side of NE–1 should have about −10V on mark and around −45V on space. The grid of V–8 cannot go very far positive as the cathode is at ground potential.

THE MAINLINE "ST–3" RTTY DEMODULATOR (Fig 5.41 overleaf)

The Mainline ST–3 was the first rtty demodulator using the new operational amplifiers to be published. A second unit could have been used for the slicer, but in this case there would have been a slight increase in cost.

Features of the Mainline ST-3

1. DC coupled from input to printer.
2. Excellent limiting to −60dB or more.
3. Uses one integrated "op amp", 10 diodes and 12 transistors.
4. Offers "autoprint" with motor control that ignores cw and voice.
5. Has 30s motor delay.
6. Optional scope or tuning meter provisions.
7. Uses a 160V loop for optimum printer operation.
8. Has a well-designed linear discriminator.
9. Copies any shift from less than 20 to more than 1,000.
10. May be used for repeating (retransmit) with no changes.
11. Uses only parts easily obtained from any general supplier.

Disadvantages

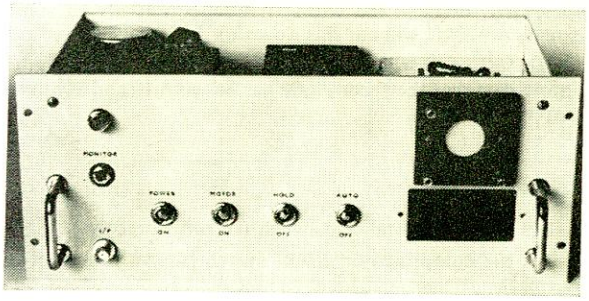
This unit was built primarily for those interested in a low-cost demodulator that offered full automatic features. As such, it has only a R/C low-pass filter. It has no threshold computer, and thus will not copy mark only or space only. No provision, therefore, is added for limiterless copy.

The Input Section

With a loudspeaker running at "normal" level for rtty, the output at 500Ω would be approximately −5dB. The output at 3Ω would be around −25dB. The ST–3 will copy down to less than −60dB input so it can be connected directly to the speaker. However, if this is done, it would be better if the volume were turned right up on the receiver and the speaker level adjusted with a dropping resistor.

The bandpass input filter shown in **Fig 5.41** may be added and will be beneficial if the unit is to be used on the hf bands. If the receiver has a 3Ω output only, good matching may be achieved by winding about 30 turns of thin wire around the input toroid and connecting this directly to the 3Ω source.

The two diodes D1 and D2 are not used for limiting, but for protection to the op amp. Its input is limited to around 1·5V and on the 500Ω tap it is quite possible on some receivers to get as much as 30V with the volume control right up.



An ST-3 demodulator built by G3LLZ. The circuit diagram is shown on p 5.19.

The Limiter Stage

Operational amplifiers normally require two supply voltages in order to work symmetrically around ground. In the ST–3, a voltage-divider network is used so that the input is half way between ground and +12V. As a result the output voltage with no input will also be 6V. As the input varies, the output will swing ±6V. When the audio is separated from the dc component in the filter stage, this +6V is removed. This system makes it possible to use the op amp with only one supply voltage.

The Filter Stage

This uses 88mH toroids in a linear discriminator. They are about 185 cycles wide at the −3dB points and around 290 cycles wide at the −6dB points with good crossover near 2,550. They also have good balance with respect to noise input.

The Detector Stage

Full-wave rectification is used for better filtering. Germanium diodes with low forward voltage drop are used for D3, D4, D5 and D6. Silicon diodes are used (D7 and D8) for the autoprint circuit.

The Tuning Indicator

On vhf a tuning meter is of little use. On hf bands some form of tuning indicator is needed. The most simple would be to attach an external vtvm to point "A". This reads negative voltage (about 2·4V) for either mark or space when both are tuned correctly. **Fig 5.41** shows how an ordinary milliammeter may be added if desired. By using an emitter-follower circuit, the input impedance in this case will be about 200,000Ω or so.

The Slicer Stage

This is just a cascaded series of transistors to give high gain. The detector output is only about ±1·5V, so the input stage was designed to have an impedance of around 100,000Ω in order to have minimum effect on the detector circuit. The following stages merely raise the gain to where it will adequately control the keyer. For 850 shift, it could have been accomplished with two less transistors. This circuit gives enough gain to copy shifts of less than 20 cycles.

The Standby Switch S–1

When S–1 is closed, Q4 then causes the keyer Q5 to go to mark. The impedance at the point where S–1 is attached is only approximately 300Ω. The 0·001 capacitor was added for bypassing any rf that might be present when transmitting. A remote standby line may be added in parallel with S–1 if desired. The relay contacts K–1A are not needed, and were added primarily to show how they would be used if motor delay control was not required. As shown, they do prevent the loop from going to space until the motor has been turned on. The autoprint section accomplishes the same thing, however.

The Keyer Stage

This is a 300V transistor. Literally any high voltage npn transistor may be used. The network hooked to the collector absorbs the back emf generated by the inductance in the selector magnets when they open for space. This back emf is around 75V for 60mA operation and around 150V for 20mA operation. Q5 pulls only 0·012W on mark and needs no heat sink.

The afsk Driver

As shown, this will drive most afsk units that require conduction on mark. It will also drive fsk transmitters requiring conduction on mark such as the Collins S-Line and other SSB type transmitters. This circuit will provide about 5mA conduction current to a germanium diode as normally used in fsk keyers.

The Autoprint Section

This portion is based on the concept developed by Keith Peterson for the Mainline TT/L RTTY Demodulator. Since cw is rarely as much as 50 per cent key down, and voice is rarely over 30 per cent average, any system that would require an average attack-to-release of say 70–80 per cent would ignore cw and voice. Since rtty is essentially 100 per cent key down, all that is needed is to sample both the mark and space channels with a system that requires a high average charge level. By making the drop-out time approximately 1s, the unit would then need about 3–4s of attack time to fulfil these requirements. The 1s will guard against momentary signal loss due to static bursts, noise peaks, etc, and 4s attack time then integrates over such a long period of time that peak fluctuations have little effect. Thus little or no filtering ahead of the autoprint system is needed.

Q6 is biased so that with no signal it conducts, causing the large 150μF capacitor to be charged fully (about 2·4V in this circuit). This in turn conducts Q8 with a few micro-amperes of current, which causes Q9 to conduct and this in turn causes the printer to be held in mark. At the same time, the collector voltage at Q9 is about 0·2V so the 20μF capacitor has no charge, Q11 does not conduct and Q12 does not turn on the relay. Thus the motor is off.

When a signal appears it puts out a negative voltage at point "A", this causes the voltage on the base of Q6 to fall and it cuts off. Q7 no longer conducts, so the 150μF capacitor slowly discharges through the 27kΩ resistor. When the voltage falls to about 1·7V, Q8 stops conducting, Q9 no longer conducts and now Q10 stops conducting, so now the printer gets its signal from Q2 and the detector circuit. At the same time, the voltage on the collector of Q9 is high and the 20μF capacitor charges quickly, allowing Q11 to conduct. This causes Q12 to conduct and this turns the relay on which starts the printer motor.

When the signal stops, Q6 again conducts, Q7 conducts, and now charges the 150μF capacitor. In about 1s it has charged enough to turn on Q8 and this causes Q9 and Q10 to conduct, putting the unit back into mark once more. Now the 20μF capacitor bleeds off slowly through the 1MΩ resistor and the emitter-follower. The capacitor has been charged to approximately 11V and must discharge to about 0·6V before Q11 stops conducting. This will take about 30s. At that time, the motor will shut off.

Why Have Motor Delay?

On hf, where lengthy QSOs are customary, some stations must send cw after terminating each transmission. It may be 10–15s from the time one rtty signal stops until another starts, due to cw, station change-over delays, etc. If no motor delay were provided, the motor would be constantly turning on and off at the end of each transmission. With 30s delay, the motor will normally stay on until the QSO has terminated. This makes continuous monitoring via "autoprint" entirely practical.

Adjustments

The input should be short-circuited to common and the 10kΩ potentiometer on the limiter adjusted so that the output voltage on pin 7 is approximately half that of the supply voltage at pin 3. This balances the "offset input voltage" so that the "op amp" will have maximum gain.

The 10kΩ potentiometer on the output is adjusted so that mark and space have equal voltages as measured at point "A".

The filters may be tuned to 2,125Hz and 2,975Hz using the capacitors specified and removing an equal number of turns from each of the two windings on each toroid.

The 100kΩ resistor on the base of Q6 sets the point at which Q6 operates with respect to the incoming signal. The value shown should give ±150–175 cycles bandwidth of operation on the autoprint. That is, a signal can drift somewhat, or have the wrong frequency initially to some extent. A 120kΩ will cut this down to ±100 cycles.

The 56Ω resistor in the low-voltage power supply may be adjusted so that the zener diode has between 10 and 30mil of current through it.

The Switches

S–1 is the receive-standby switch (shown in receive).

S–2 is the autoprint normal-off switch (shown in autoprint normal).

S–3 is the motor on switch (shown in automatic).

S–4 is the power on-off switch.

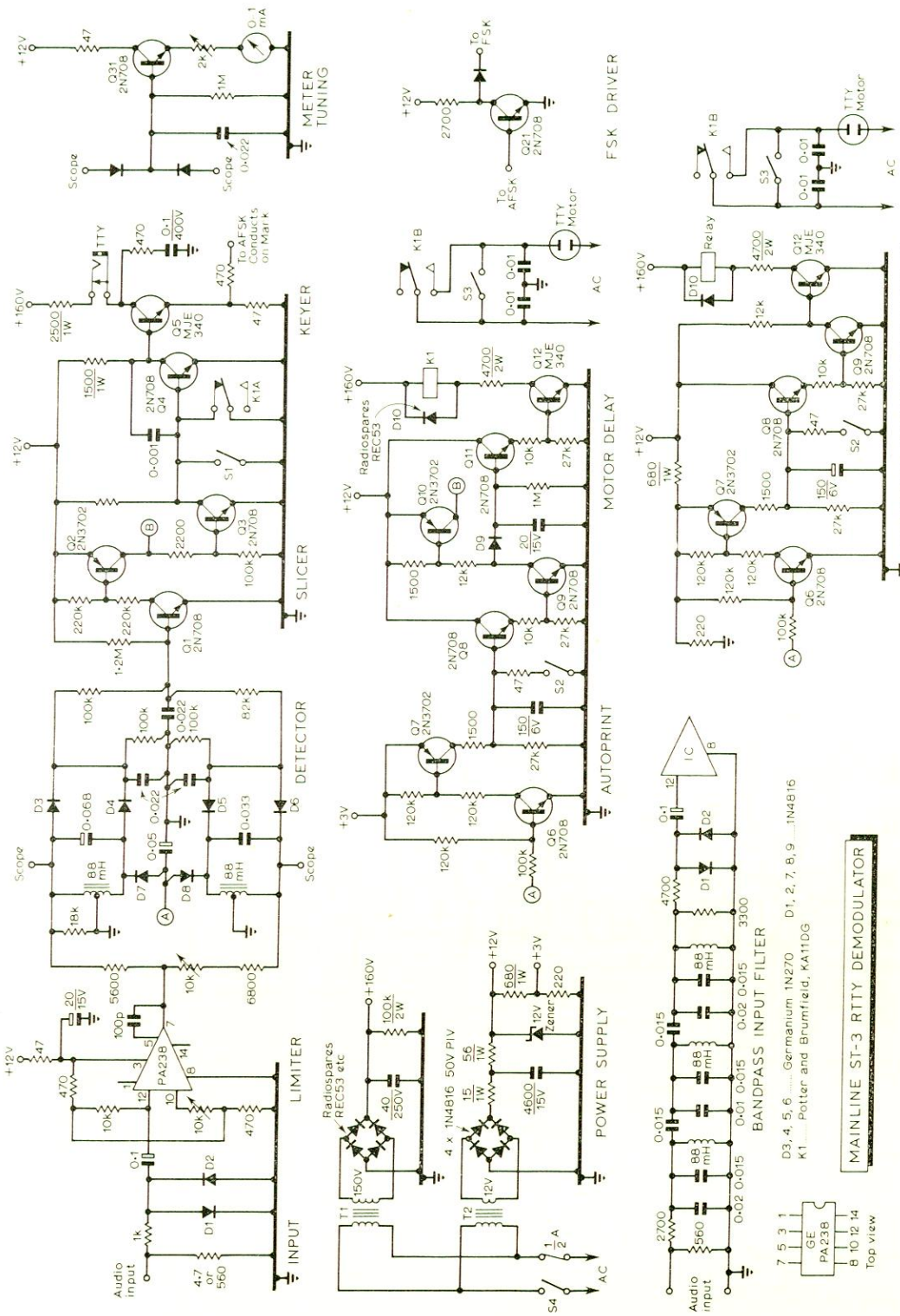


Fig 5.41. The circuit diagram of the Mainline ST-3 rtty demodulator.

"MAINLINE ST-5": SIMPLE, SOLID STATE RTTY DEMODULATOR (Fig 5.42)

Brief Description of the ST-5

This unit uses a 709C linear integrated operational amplifier ("op amp") for a limiter, and a second 709C for a slicer (trigger) stage. It uses a Motorola MJE-340 300V transistor as a keyer to turn the printer from mark to space. It offers the identical "floating loop" power supply developed for the TT/L. It has a well-balanced linear discriminator for 850 shift that gives the user the option of normal 2,125–2,975 tones. It can quickly be adapted to 170 shift although this is not shown on the basic diagram—it will be explained in the text later. A "plus-plus" take-off is provided for a tuning meter, and scope points are shown.

The Limiter

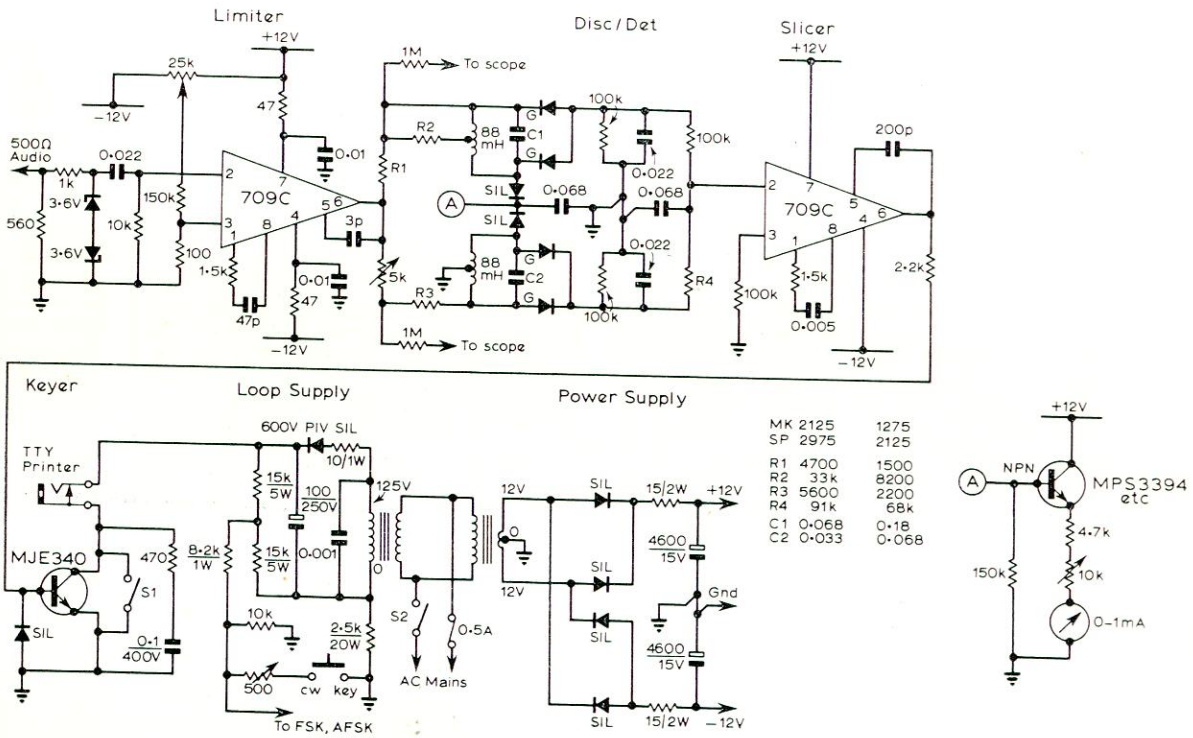
The 709C offers gain so fantastic it is hard to describe the potential performance available. Where something like the TT/L offered perhaps 50dB of limiting, the 709C offers closer to 90dB. This would be comparable to raising the voltage in the TT/L from say 230 to nearly 7,500V! There are other advantages as well, since this takes the place of three valves and two transformers; is all dc coupled; responds up to 10MHz (which puts the recovery time in the micro-second category); is inexpensive and no larger than many transistors. It has a good output swing of better than ±10V. With the circuit shown, it will start to limit on a signal as low as 200μV input level. A simple one-pole R/C high-pass filter is included in the input to keep the 50Hz hum in the receiver audio from reaching the limiter, thus some of the advantages of a bandpass input filter are realized.

The Discriminator/Detector

With simple one-toroid per channel filters, it is rather difficult to design a proper discriminator. A lot of problems are inherent that most casual observers would not consider. Indeed, when looking at the circuits offered by many designers, no consideration at all appears to have been given some of these areas. "Q" is dependent on frequency, and so is impedance and output voltage. Bandwidth is dependent upon "Q". To simplify the matters we can say that if you merely put a capacitor across a 88mH toroid, the bandwidth will be too narrow to be useful in rtty, it will not be the same for two different frequencies such as 2,125–2,975 (it will be worse for 1,275–2,125) and the voltage developed across the filter with a given input will be considerably different for the two frequencies. Hence the designer has to take all these things into account, and at the same time realize that the "total area under the curve" affects the general noise balance as well. Hence it is no simple matter to get a well-designed linear discriminator that exhibits relatively equal bandwidth for mark and space, has equal output voltages, good linearity (proper cross over) and reasonable noise immunity.

The detector stage on most demodulators is half-wave rectification, and on some units, voltage doublers are used,

Fig 5.42. The circuit diagram of the Mainline ST-5 Solid State-rtty demodulator. *Note: junction of R2 and centre—tap of toroid to go to chassis.*



making the filtering problem even more difficult. The Mainline ST– series use full-wave detection, which results in much less ripple and easier and more effective filtering.

The Low-pass Filter

Most simple demodulators do not offer any low-pass filtering at all. The best units have complex three-pole Butterworth minimum bandwidth filters that usually take a large and expensive inductor plus an isolation stage at either end. The ST–5 has a single-pole R/C filter that does an adequate job of removing the audio ripple from the dc keying signal.

The Slicer

Another of the 709C op amps is used. Since dc signals are now being dealt with instead of audio, you will notice different "compensating networks" are shown at points 1–8 and 5–6. This slicer has so much gain that a signal variation as low as 1–2Hz will caue the keyer to switch completely from mark to space. Shifts as small as 3–4Hz then could easily be copied if the operator had a steady enough hand!

The Keyer

This is the identical keyer stage that will be used in the deluxe ST–6. The MJE–340 is a 300V transistor. Although capable of handling power up to 25W it is used here as a saturated switch that is either "on" or "off". Even with a 60mil loop, the keyer therefore pulls something like 0·012W in mark, due to the very low saturated collector-emitter voltage of only 0·2V. Under normal circumstances, it is thus virtually indestructible in rtty use. It is cut off hard for space, by negative voltage from the slicer. The diode at the base diverts this excessive negative voltage to ground which keeps the base-emitter junction from acting like a zener diode when the slicer goes to negative 10V.

A spike-absorbing network goes from collector-to-ground to reduce the "back emf" caused by the selector magnet inductance as it switches from space back to mark.

The Loop Supply

This is a similar concept to that developed for the TT/L. The resistor values are changed somewhat since the 6W6 vacuum tube in the TT/L acts like a switching resistor, while the solid-state keyer in the ST–5 acts more like a typical switch. The fsk output point will supply a minus-plus voltage as it switches from mark to space; thus it offers excellent adaptability to various types of transmitters, some of which need "conduct-on-mark" instead of the normal "conduct-on-space". If you are "upside-down" merely reverse the diode in your transmitter's keyer and it should then be normal.

Standby Switch

Shorting the standby switch S1 puts the printer into mark configuration. The voltage across the switch contacts is normally 0·2V for mark and perhaps 175V for space.

The Power Supply

Practically any 24V centre-tapped transformer will work. The op amps can take up to ±18V on them, so anything from 10–18V± is suiable. Regulation is not needed on this unit and in fact offers very little advantage. Any change in the transformer will be reflected by an equal change up or down on both supplies at the same time, and cancel out. The voltage at pin 3 of the limiter will not matter once initially set for the nominal power supply output voltage. It is only a few millivolts and a radical change in the power supply voltage would have negligible effect, if any.

If the voltage is more than 15–16V, increase the size of the 15Ω resistors until the output is correct. This offers the possibility of any of a number of power transformers being suitable.

Tuning the Filters

For the most accurate tuning, a counter or accurate audio generator, is needed. Otherwise, just put a 0·068 capacitor across a 88mH toroid and you'll come out "close enough" to 2125, although the exact right capacitance is 0·06374, assuming no error in the capacitor value. The toroids are connected in a normal "series" manner with the middle connection of the two windings grounded as shown. The values for the capacitors shown in the table are quite accurate and assuming 10 per cent capacitors, this should be close enough to mark and space to be happy.

Adjusting the ST–5

With no input signal or with the input grounded, put a voltmeter at pin 6 of the limiter, or any place connected directly to pin 6, such as the one side of the 5kΩ potentiometer. This is a very low impedance point so you need not use a vtvm for the purpose. Any voltmeter will do. Adjust the 25kΩ potentiometer until there are zero volts at pin 6.

Now put the voltmeter at point "A" or refer to the tuning meter later in the text. Go from mark to space on the input and adjust the 5kΩ potentiometer until the meter reads a similar amount of voltage for both signals. This completes the adjustments.

The Tuning Meter

Fig 5.42 shows a suitable 0–1mA meter used for tuning purposes. If the meter flickers as the station goes from mark to space, it is not tuned correctly. A capacitor may be placed across the meter if desired to dampen its oscillations somewhat. This may be necessary if using an inexpensive imported meter. Although a scope display is preferred by most serious enthusiasts, the meter display is quite adequate, and more accurate than many might at first think.

170 Shift

If it is wished to occasionally copy "narrow shift", add a 0·022 capacitor in series with a toggle switch and put this combination across the space toroid. This automatically will change the 2,975 frequency to very close to 2,295. However, the balance at point "A" will be upset somewhat, and it is merely an expediency which will give reasonably good 170 shift.

If using the 1,275–2,125 tones, it is needed to put two capacitors in parallel—a 0·068 and a 0·0068—then place the switch in series with these two parallel capacitors and then

put this combination across the space toroid. This changes the 2,125 space frequency to about 1,445. Again this is only an expediency, and does not give optimum filter balance, etc.

Audio Input

If the station receiver does not have a 500Ω tap, it is permissible to connect the ST–5 directly across the speaker. However, by so doing about 20–25dB of potential performance is sacrificed.

Components

The diodes marked G are 1N270, germanium, those marked SIL are any silicon type, except the one in the loop power supply which should be 400V or better. The zener diodes in the limiter input can be replaced with two silicone diodes if cost is essential. In that event they should be wired in opposing parallel, not in series as is shown for the zeners. This is a protective device to keep the op amp input under the maximum allowed, which is around ±5V peak to peak. The zeners may be left off entirely, but it is possible to ruin the op amp if the receiver is inadvertently loudly tuned. It is possible on some receivers to peak 50V at the 500Ω tap if the volume control is fully turned up.

MAINLINE: SOLID STATE, ST–6 DEMODULATOR (Fig 5.43)

Introduction

The Mainline ST–6 RTTY Demodulator is similar in design and layout to the Mainline TT/L–2 (*RTTY Journal* September 1967; *QST* May 1968). It is all solid-state, using a number of 709C operational amplifiers in addition to other transistor devices. The Mainline TT/L–2 was an up-graded Mainline TT/L (*RTTY Journal* November 1964; *QST* August 1965). These valve-type rtty demodulators have been extremely popular with serious rtty enthusiasts. The ST–6 follows in this tradition.

Features

The ST–6 has an outstanding limiter, a well-designed linear discriminator, full-wave detection, a three-pole active low-pass Butterworth filter, a threshold corrector allowing limiterless ("AM") copy, a high-gain slicer permitting extremely narrow shift signals to be copied normally, a 300V loop keyer transistor, the well-known "Mainline floating loop" offering optimum fsk keying of the transmitter, and a 180V loop supply.

In addition, optional bandpass input filters for 850 and 170 shift are provided, automatic printer control with motor delay ("autostart") that ignores voice or cw, and "anti-space" system that immediately locks up the printer if the signal goes to space longer than a normal rtty character, simplified switching that provides good flexibility, and a symmetrical ±12V power supply that is adequately regulated. The unit has a limiter on-off switch, a fast-slow autostart switch for rapid break-in, a manual motor "on" switch, a meter for tuning signals, remote standby provisions, etc.

Other "ST– –" Units

To keep the record straight, the ST–1 was never published. The ST–2 was a nice unit for vhf without autostart motor delay. The ST–3 (*RTTY Journal* September 1968; *QST* April 1970) was the same unit having motor delay control in addition to autostart. The ST–5 was a simple unit using two op amps and one 300V keyer stage (*RTTY Journal* May 1970; *Ham Radio* September 1970) and no autostart features, being intended for the beginner who needs a simple, easy-to-build unit. The ST–4 was only for 170 shift.

The 709C Operational Amplifier

This unit is the "work-horse" of operational amplifiers. The cost has dropped to the point they are very inexpensive even in small quantities of only one or more. They have in excess of 90dB gain when used in "open loop", and are good to 10MHz as well.

They can take as much as ±18V, although it is customary to use them at ±12V. They have very low offset input voltage which can be easily balanced. As they cascade numerous differential amplifiers for high-gain, they clip symmetrically, making an excellent limiter or voltage comparator, as well as a good linear amplifier when controlled feedback is added.

They do, however, require frequency compensation to be added externally, the amount depending upon the gain to which the circuit is expected to amplify.

Other, Newer, Operational Amplifiers

To be sure, there are other op amps having higher gain, will accept greater input voltages without damage, are not subject to "lock up" with excessive input voltages, and do not require external compensation. However, these units are intended primarily for use in logic circuits, where very low frequencies (almost "dc") are used. These units make very poor limiters when compared at audio frequencies with the 709C. They would be excellent for use in the ST–6 at places other than OA–1 and OA–2. However, their cost is such you can use the 709C with proper compensation and still save money. The difference in amplification between 90dB and 100dB is insignificant in this case, since even 90dB would be the equivalent of running the TT/L–2 (valve-type demodulator) at perhaps 7,500V on the anode of each valve.

The Limiter

The input is designed so that a bandpass input filter is not required. A simple single-section L/C high-pass filter reduces the 50Hz output of the receiver to an insignificant level, thus allowing the limiter to "reach into" the receiver's noise level for the signal. Zener diodes are provided to protect the input of the amp from possible overload. They are not intended as part of the limiting action at all, and normally are not called upon to do a thing. The op amp itself is run at full "open loop" for limiting. A signal as small as 200μV will produce clipping, and the output waveform with normal input signals is "story-book" square waveform with amplitudes approaching that of the supply voltage itself.

A 47kΩ resistor is provided for changing the amplification to a controlled amount, for "limiterless a.m." detection should the operator choose to use this system. Since limiterless operation and autostart are not compatible in this type of circuitry, placing the switch to "limiter off" also disables the autostart, and keeps the motor running automatically.

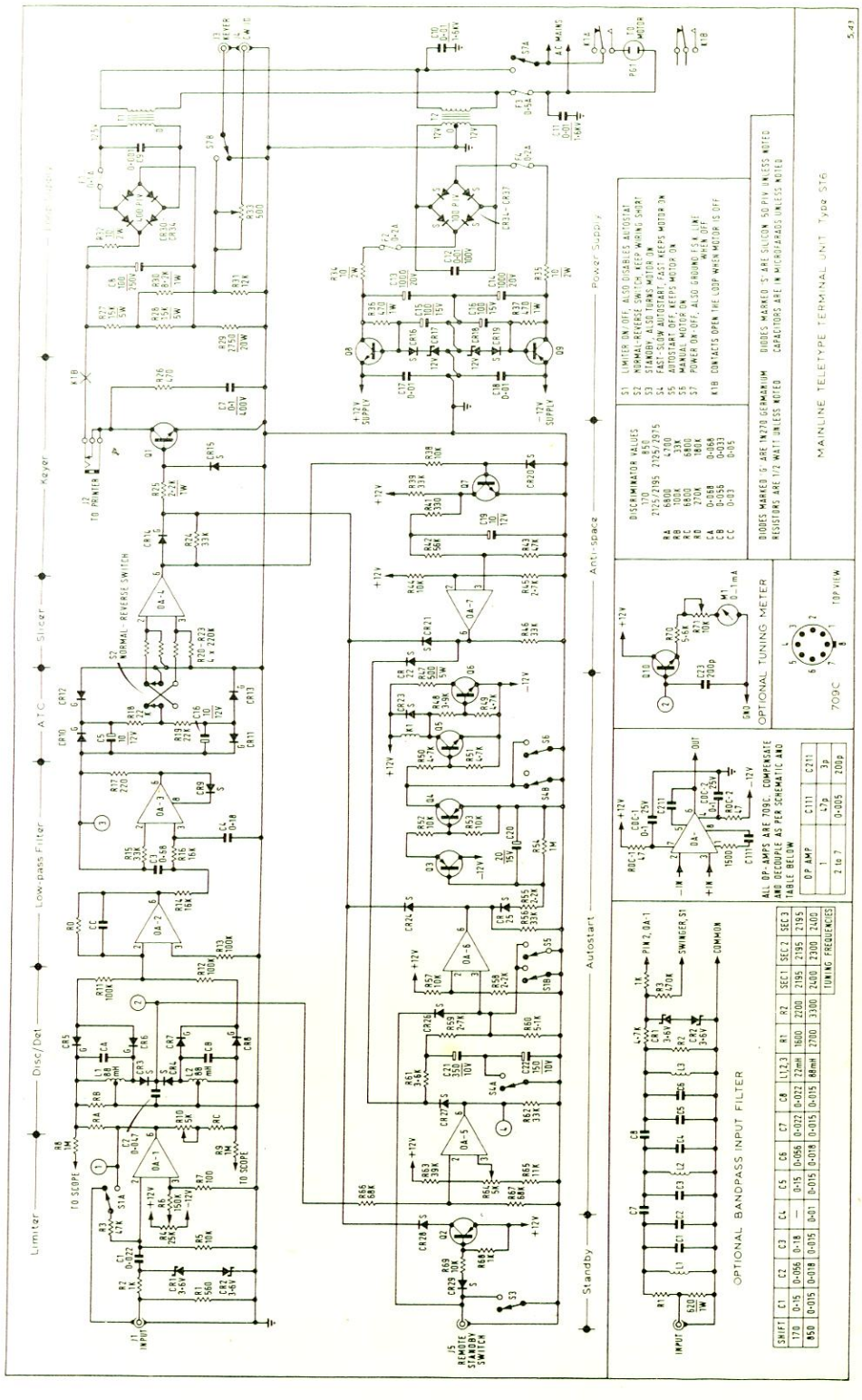

Limiter
Disc/Det
Low-pass Filter
A.T.C.
Slicer
Keyer
Standby
Autostart
Anti-space
Power Supply
OPTIONAL BANDPASS INPUT FILTER
OPTIONAL TUNING METER
MAINLINE TELETYPE TERMINAL UNIT Type ST6
Components List
All resistors are ¼–½W unless otherwise stated.
Relay K1. Any 24V (approximately 500Ω dc resistance), dpdt.
C7 0·1mf 400V.
The 0·1mf capacitors used on pins 4 and 7 of each op amp are 25V disc ceramics.
Diodes marked "G" are 1N270 germanium.
Diodes marked S are silicon 50piv except those in the loop supply which must be at least 400piv.
3·6V zener diodes are 1N5227, etc.
12V zener diodes are 1W 1N4742, etc.
Q1: MJE-340.
Q2, Q3, Q4: MPS 3703, etc.
Q5, Q6: MPS 6565.
Q7, Q10: MPS 3394.
Q8: MJE-340, 40635, 40314, etc.
Q9: MJE-370, 40537, 40362.
T2: 24V CT, 400mA.
Toroids: 88mH.

Fig 5.43. The circuit diagram of the Mainline ST-6 Solid State-rtty demodulator.

The Bandpass-input Filter(s)

Three-pole Butterworth bandpass filters are offered for the serious enthusiast. These are three toroids each. The 850-shift bandpass filter is about 1kHz wide and the toroids are used in series configuration for 88mH. For 170 shift, they are wired in parallel (both outside wires together, both "pig tails" together) for 22mH. This keeps the impedances similar for the two units. The bandwidth of the 170 shift filter is about 275Hz. These filters are based on 2,125 mark tone. No filters are offered for those requiring other, unusual, audio tones. If the bandpass input filters are used, the 0·022mF capacitor and the 10kΩ resistor to ground (pin 2 or OA–1) are not used.

The Linear Discriminator

Optimum filters for mark and space channels would probably be three-pole Butterworth types using three toroids for each filter. However, excellent results are obtained from a well-designed linear discriminator using only one toroid for each channel. A great deal of attention must be given with such a simple set of filters to achieve good noise immunity, good zero crossover, equal bandwidth and equal output voltages. This is not simple, particularly when in addition it would be desirable to get both 170 and 850 shift filters to give similar output voltages. The filters in the ST–6 should meet these requirements nicely, if the exact values of components are used. The size of the capacitors are only approximate, as the toroids themselves have 2–3 per cent latitude and the capacitors will probably be only 10 per cent types as well. This could easily result in an error of 100Hz and more, so careful attention to tuning each toroid is most worth while.

A "plus-plus line" is added to the discriminator to provide a signal for the autostart system as well as to the tuning meter.

The Detectors

Full-wave detection is employed for easiest filtering of the ripple content. The ST– series units are unique in this feature. Germanium diodes are used, as their forward voltage drop is only 0·2V or less, as compared with about 0·7V for a typical silicon diode. This gives some additional dynamic range to this section. As the germanium types do not have high reverse movement, they can only be used in relatively low impedance areas.

It will be noticed no actual filtering is done in the detector circuit itself, another unique feature of the ST–6. All the filtering is done in the three-pole active low-pass filter, thus extremely rapid recovery time is possible from things such as noise bursts, static impulses, etc.

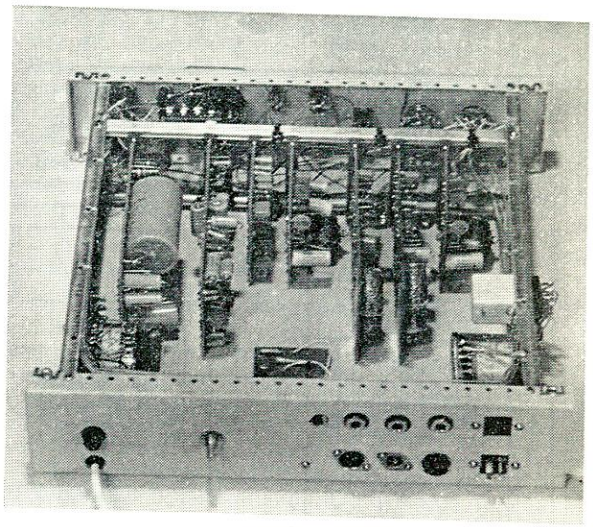
The Low-pass Filter

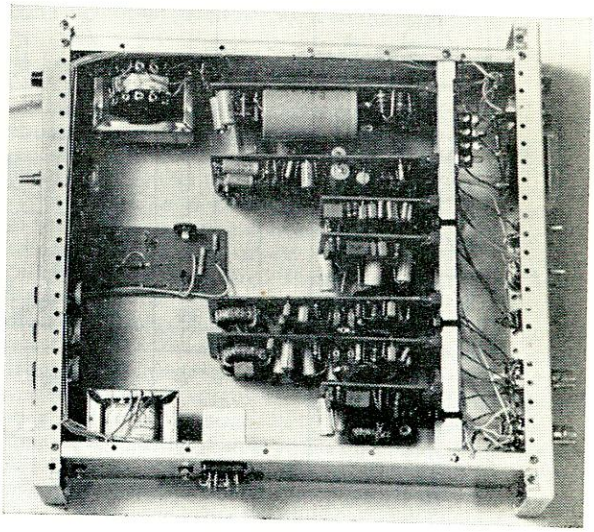
The Mainline ST–6 is probably the first rtty demodulator to be offered the amateur using an optimum bandwidth three-pole Butterworth low-pass filter of an "active" design, that is, with feedback amplifiers rather than with inductors or other "passive" components normally used. This offers low cost, small size, controlled performance, negligible weight, and results that can be easily duplicated from one unit to the other with modest-cost components. (The inductor used in the TT/L low-pass filter had extremely sloppy tolerances of about ±50 per cent, plus additional problems such as magnetic hum, large size, etc.)

The low-pass filter was designed for optimum 60 speed use. It can easily be changed (via two resistors and a capacitor) to 100 speed if needed. It cuts off at 27·3Hz dc for a steady mark input.

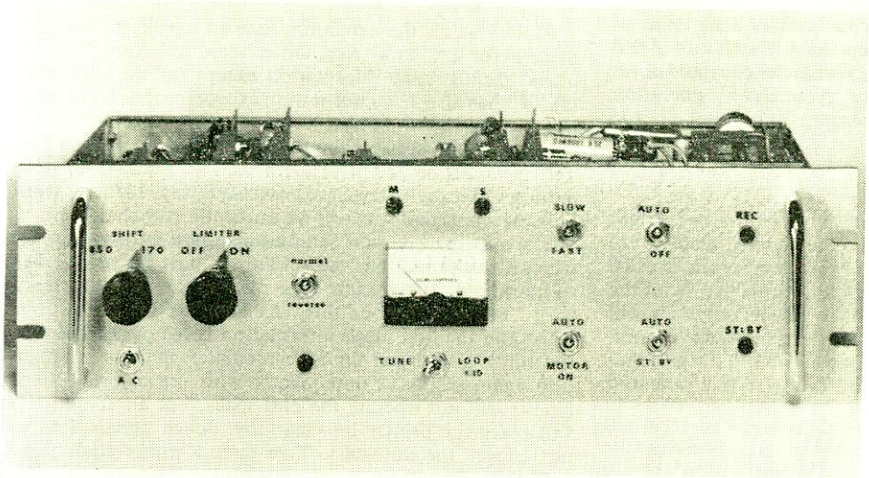
The Threshold Corrector

For limiterless a.m. copy, some means of balancing the mark-space signals from the low-pass filter is required in order that the slicer can properly change at the right time. The ST–6 thus has an automatic threshold corrector, called the "atc" for short. Again, germanium diodes are used to



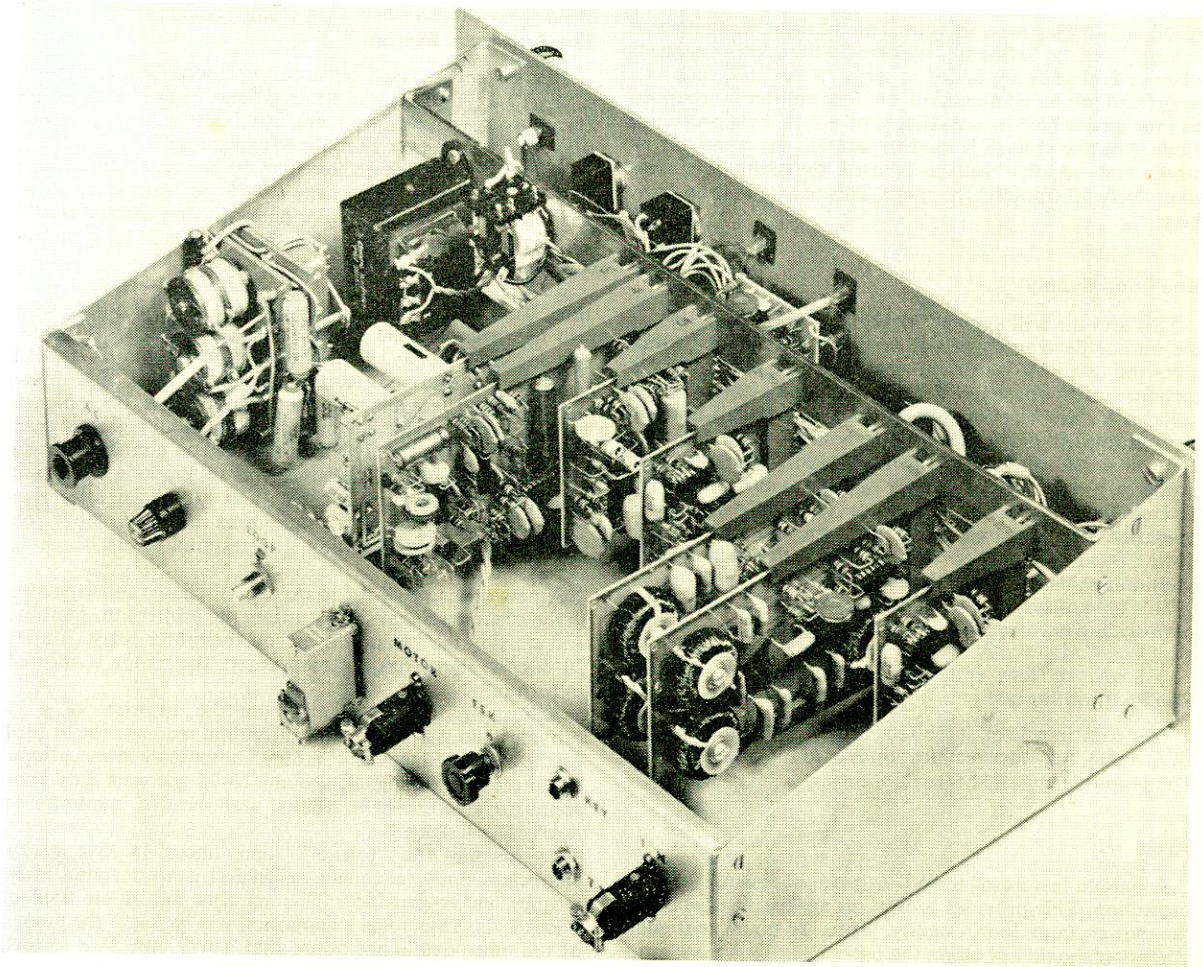


A version of the ST-6 built by GM8BJJ, showing the layout as seen from the rear (upper view) and from above (lower view).



Another version of the ST-6: this one was built by G8LT. The front panel layout.

Rear view of the ST-6 as built by G8LT.



give the maximum possible dynamic range. This circuit was explained in some detail in previous articles (see issue of *RTTY Journal* November 1964, reprinted March and April *RTTY Journal* 1970). It allows single-channel copy and combines the mark-space signals for symmetrical operation around the ground axis of the slicer.

The Slicer

This is just a "wide open" 709C. Other op amps would work as well in this position since the signals handled are very low frequency (maximum of 22ms reversals for 60 speed). The slicer has so much gain and the signal from the low-pass filter is so clean that shifts as low as only 1Hz will adequately flip the slicer from full mark to full space output. This with the 850 shift discriminator as well! This is rather silly, in fact, but adequately illustrates the terrific potential of the op amps used in the ST–6.

The Keyer

This is a Motorola MJE–340 rated at 25W and 300V. Other types are equally suitable, if rated from 300V or more. A spike-absorbing network is used on the collector to prevent damage from the back-emf developed in the selector magnets when several units are added in series to the unit, such as a reperf and printer combination, etc. The emitter is grounded and the base is held to a maximum of −0·7V by a protective diode. Positive voltage is used to saturate the transistor on mark, and negative voltage is used to assure it cutting completely off (rapidly) for space. This results in little or no bias.

The Loop Supply

This uses the well known "Mainline floating loop" system the author developed for the original TT/L. This method gives the usual 180V or so to the keying stage for low distortion, but the principle feature is the plus-minus keying voltages for the fsk system in the transmitter. This not only gives saturated diode current for best fsk operation, but controlled cut-off voltage for back-biasing the fsk diode properly. With this type of fsk voltage you only need to reverse the direction of the diode to get "right-sideup" operation if you are reported to be transmitting "upside-down" from normal. Few other systems offer such a simple solution to this type of problem.

This type of system also offers simple and effective means of providing narrow shift cw identification.

The Power Supply

This uses transistor-stabilized, zener-regulated + and − 12V. Again, full-wave rectification is used for easiest filtering. The output is bypassed for rf.

Fuses

A unique feature of the ST–6 is the liberal use of fused protection. This provides protection against dead shorts in the power (and loop) supply. Thus 24-hour unattended operation should not alarm the user.

The Anti-space Circuit

At 45·5 bauds the maximum time an rtty signal can go to space is for a "blank" key. Other than this, for a "T". The blank has all space information except for the stop pulse, the "T" has all space information except for the last information bit plus the stop pulse.

For a blank, this maximum time would be 132ms, for a "T" it would be 110ms. Thus if we had a means of determining when the space signal exceeded, say, 132ms it would indicate the signal was not an authentic rtty character.

The anti-space circuit samples all space information, and when it substantially exceeds 132ms it puts the printer back to markhold, at the same time placing the autostart circuit to a "no signal" condition. As soon as the space signal stops and the first mark information is fed out of the slicer, the unit is discharged almost immediately and normal operation again results. Consequently with normal rtty, steady blanks will not operate the anti-space, but anything longer will place the printer into standby. Space signals thus will not trigger the autostart. This circuit works equally well with the autostart on or off, or with the limiter on or off, or with "straddle-tuned copy".

The Autostart System

This system is based on a concept described previously in the TT/L, TT/L–2, and ST–3 articles. However, there are always some readers who are not familiar with previous discussions, so here is a simplified explanation.

Morse code is perhaps less than 50 per cent "duty time" (key down). Voice is perhaps 20–30 per cent duty time, depending on things like voice pattern, compressors, intelligence of the operator to keep the audio gain at a proper level, etc.

RTTY on the other hand is actually 100 per cent duty time. Thus we develop a method by which a high-duty time will trip a circuit and a low-duty time will not, it should respond only to rtty. Thus the autostart in the ST–6 (like the others mentioned) samples both the mark and space channels and combines their output as a one-polarity voltage. As long as this voltage is substantially greater than the trigger point for which the system is adjusted, it will charge a capacitor. If it charges this system long enough, it will then overcome a fixed bias and turn on a relay that starts the motor and at the same time remove a "hold" on the printer magnets allowing it to respond to the incoming signal.

A network is provided to quickly discharge the capacitor in the event the signal stops, putting the printer into standby, and starting the "count-down" on the motor relay. If after 20–30s the signal has not reappeared, the motor is allowed to turn off.

A turn-on to turn-off ratio on the autostart of 4 : 1 provides about a 75 per cent duty time requirement to turn on the printer. Since static, fading, momentary interruptions, etc affect the rtty signal, around 70–75 per cent duty time seems to give excellent results, and suitable immunity to nearly all cw signals.

By keeping the "turn-off" time about 1s (five to six characters time), adequate protection against static, noise crashes, etc is provided. This requires a turn-on time of about 3–4s. Thus some information will be lost if the person at the other end is not aware that it will take 3–4s to turn

on your unit. However, this is only a small penalty to pay to achieve automatic printer control. It is also possible to have a "fast" autostart system which operates three or four times faster than this. However, poor conditions will give adverse results, so this system is used normally only when the operator is present and working "quick break" etc.

Other ratios may be used, and will in fact keep the ST–6 from responding at all to weak signals that would probably not be copied reliably anyway.

The Remote Standby Line

A remote standby jack is provided on the ST–6. When shorted to ground, it places the unit in standby and also turns off the autostart, turning the motor on or keeping it on if it had been already running. This allows monitoring the incoming signal from the receiver while transmitting, but keeps the printer from responding at all, except from its own keyboard. It also keeps the motor running during the time on the air. On the other hand, if this remote switch is located at the printer, it allows turning the printer on without touching the ST–6 itself.

Important: A second switch at the printer would be called the "transmit" switch, and would also parallel the remote standby line. It would be a dpst or dpdt switch, one pole would turn the transmitter on, the other pole would short the remote standby line, thus "single-switch" operation is provided. If the motor was not running, merely turn the switch to "transmit" and both the printer and the transmitter would immediately start up.

Miscellaneous

S.1 is the limiter on-off switch. When on, it provides normal "fm" copy, when off, "a.m." (two-tone or limiterless, if you prefer). When in "limiter off" it also disables the autostart and keeps the motor running.

S.2 is the normal-reverse switch.

S.3 is the standby switch, places the unit in markhold and also disables the autostart, which keeps the motor on or turns it on if it was off. The remote standby switch does the same thing, but is conveniently located at the printer; also on the transmit switch.

S.4 is the fast-slow autostart switch, for "quick break" where the operator is present and the 3–4s turn-on time is a nuisance but automatic printer control is still desired—also in "fast" keeps the motor running indefinitely.

S.5 is the autostart "off" switch, this also keeps the motor running. There may be times when it is wished to have complete manual control, like during bad conditions when running fast break, etc.

S.6 is the manual motor "on" switch.

S.7 is the 240V ac power on-off switch, this also opens the fsk line when the power is off, to prevent any hum loops from the transmitter to ground.

Tune-up

The ST–6 was designed so that tune-up and alignment procedures are extremely simple, and once adjusted should not require any further adjustment. All that is needed is a normal dc voltmeter reading to at least 12–15V.

First—disconnect the audio input or short the input to ground. Put the voltmeter on test point 1 (output of the limiter op amp) and adjust the 25kΩ potentiometer on the input to pin 3 of OA–1 for 0V dc on the meter. It will be difficult to do and the reading will not necessarily "hold", but do the best you can and forget about it.

Second—either move the meter to test point 2, or just observe the tuning meter on the ST–6 itself, now add audio input and tune back-and-forth between mark and space signals, adjusting the 5kΩ potentiometer on the output of OA–1 so both mark and space give the same voltage. This balances the discriminator for equal output.

Third—tune to steady mark signal and adjust the 10kΩ potentiometer on the tuning meter circuit so the meter reads 70 per cent full scale. Hopefully the meter will read 0–10 and have marks each 0·1 of full scale. Then detune the input signal to where the meter reads only 60 per cent of full scale. Now adjust the autostart sensitivity potentiometer at pin 3 of OA–5 to where the voltmeter (now at test point 4) cannot make up its mind to go positive or negative. If you added the lamp drivers for "standby-receive" you can adjust the 5kΩ potentiometer to where they cannot decide which of the two lamps to display. This is a one-only adjustment.

This completes the adjustments.

The autostart sensitivity primarily sets the bandwidth to which the unit responds. The ratio of turn-on to turn-off time is set primarily by time constants in the autostart stage itself. Thus the autostart sensitivity control is inside the unit and not on the front panel as on the TT/L and TT/L–2 units.

Other "Adjustments"

There are no other potentiometers, but there are a few other things which one may wish to change. The feedback resistor on pin 2 of OA–1 (the 470kΩ) was selected for "No bandpass input filter" configuration. If using the bandpass input filter(s) change this resistor to 470kΩ. If required, it is possible to hand-pick a value that may work better in the builders' installation. This is simple to do: tune the receiver to a normal signal, advance the audio gain to the point normally used to run it, put the ST–6 in limiterless and note the tuning meter—pick a resistor that gives about normal meter reading in limiterless for that receiver—that is, if you then reduced the volume on the receiver, the meter would go to a lesser value. If this is confusing at all, just use the 470kΩ and forget about it.

For proper operation of the various circuits, it is quite important to have close to 12V from the power supply. With modest-cost zener diodes, this may or may not be the case. If the voltage is more than a ½V too high, remove the silicon diode in series with the zener diodes in the power supply, and short across where they were. If the voltage is less than 12V, add another silicon diode in series with the zeners.

The voltage at pin 2 of OA–6 should be at least 2·2V. If less than 2·2V, change the 2·2kΩ resistor to ground to say a 2·4kΩ size. If the voltage is as high as 2·5V it won't hurt anything.

On the anti-space, the 10μF capacitor (near Q7 collector) can be reduced in size. To adjust it "just right", keep reducing the value until while sending blanks the printer starts printing the letter "T" instead, then go to the next larger size of capacitor. However, the 10μF should give excellent results.

The resistor in the collector of Q6 in the autostart relay circuit should be about the same value as the dc resistance of the relay itself. A 500Ω 5W resistor is shown. Some 24V

relays are around 470Ω, some around 500Ω, it really doesn't matter all that much—this resistor merely keeps the current level in the power supply about the same whether the motor is on or off, helping keep the voltage regulation at an optimum stability.

The 3·6V zeners on the input (OA–1) may be 3·9V, but the 3·6V value allows for inexpensive 20 per cent types to be used, if getting 3·9V types, make sure they are 10 per cent types. Also 4·3V 10 per cent units could be used, but are not recommended.

Autostart Bandwidth

When the autostart potentiometer on pin 3 of OA–5 has been set as previously discussed under "tune-up", the unit will respond to signals approximately ±45Hz for the 170 shift filters and approximately ±100Hz for the 850 shift filters.

The Bandpass Input Filters

Constructors may ask what value the bandpass input filters would be where they already have excellent i.f. filters in the receiver. In this case the value of the bandpass input filters is indeed negligible with one exception, they do prevent the hum level in the receiver audio output stage from reaching the limiter. However, the input of the ST–6 (when no bandpass input filter is used) does this same thing rather nicely.

However with the bandpass input filter, it still does a lot to minimize the effect a strong nearby station will have on the limiter. If the i.f. in the receiver is rather broad (many receivers have only a 2,100Hz i.f. position, and no 400 or 1,200 filters at all), then the use of a bandpass input filter is most worth while, particularly when the operator keeps the rf gain back to where even strong signals do not completely capture the agc in the receiver.

Optional Audio Tones

Many people say they "cannot receive 2,975 audio" and must have other tones like 1,275–2.125. In almost every case, receivers *can* in fact receive 2,975, but it requires changing the bfo crystal or the carrier oscillator crystal about 1kHz from that normally used. This is usually fairly simple to do, and the results are superior to those obtained when using 1,275–2,125 audio for reasons beyond the scope of this discussion. However, for those who insist on using 1,275–2,125, here are the values:

DISCRIMINATOR VALUES FOR "LOW TONES"

	170	850
	1,275/1,445	1,275/2,125
Resistor A	2·7kΩ	1·5kΩ
Resistor B	27kΩ	8·2kΩ
Resistor C	2·7kΩ	2·2kΩ
Resistor D	240kΩ	160kΩ
Capacitor A	0·18μF	0·18μF
Capacitor B	0·12 + 0·018	0·068
Capacitor C	0·022	0·033

Voltage Measurement

These measurements will be given in either "mark and space" columns where appropriate, or in "signal—no signal" columns. All measurements were made with a *Heathkit* 10 Megohm VTVM.

OP AMP OA-1:

PIN (mark or space either one)

	1. 7·8	5. −11·4
	2. 0	6. −7·7ac
	3. 0	7. 11·8
	4. −11·8	8. 9·4

NORMAL REVERSE SWITCH: about +4 for mark, −4 for space

OP AMP OA-4: Mark signal

2. 0
3. 2·0
6. 11·0

TEST POINT 2 : 7·8 on mark for 170 shift discriminator 0V dc with ST–6 input disconnected

OP AMP OA-2 (mark input)

	1. 8·2	5. −11·4
	2. 0	6. 8·4
	3. 0	7. 11·9
	4. −11·9	8. 8·7

OP AMP OA-3

Pin	Mark	Space
1.	8·2	
2.	8.5	−8·5
3.	8·5	−8·5
4.	−11·9	
5.	−11·5	
6.	8·5	−8·5
7.	11·9	
8.	8·5	

OP AMP OA-5

	Signal	No-signal
1.	7·4	8·2
2.	3·9	0
3.	3·4	3·4
4.	−11·8	−11·8
5.	−11·0	−11·9
6.	−10·8	11·4
7.	11·8	11·8
8.	11·5	7·8

OP AMP OA-6

	Signal	No-signal
1.	7·5	8·1
2.	2·2	2·2
3.	0	4·7
4.	−11·9	−11·9
5.	−10·8	−11·9
6.	−10·8	10·8
7.	11·9	11·9
8.	11·4	7·7

OP AMP OA-7

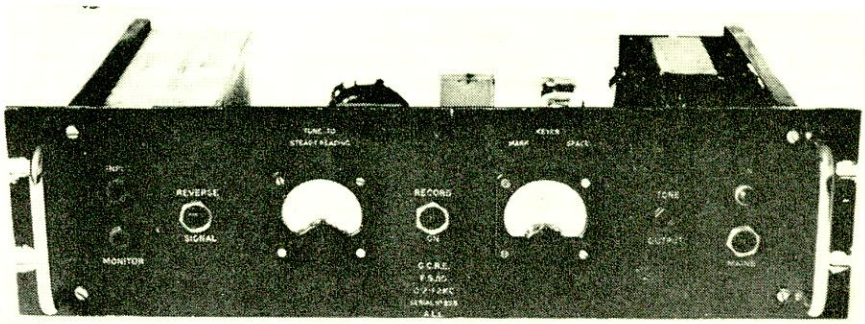
	Mark	Space
1.	7·5	8·1
2.	2·3	2·3
3.	0	4·2
4.	−11·9	−11·9
5.	−11·9	−11·9
6.	−10·8	10·8
7.	11·9	11·9
8.	11·5	11·5
Q1	**Mark**	**Space**
B	0·6	−0·7
E	0	0
C	1·0	170
Q2	**S-3 on**	**S-3 off**
B	11·3	12·0
E	12·0	12·3
C	11·9	0
Q3	**Signal**	**No-signal**
B	−10·3	0
E	−9·5	0
C	−12·0	−12·0
Q4	**Signal**	**No-signal**
B	−0·7	0
E	0	0
C	−0·03	−12·0
Q5	**Signal**	**No-signal**
B	−11·3	−12·0
E	−12·0	−12·0
C	−11·8	10·2
Q6	**Signal**	**No-signal**
B	−11·9	−11·3
E	−12·0	−12·0
C	12·0	−11·8
Q7	**Mark**	**Space**
B	0·7	−0·7
E	0	0
C	0·05	9·3

10μF CAPACITOR IN ANTI-SPACE

Mark	Space
0	9.3

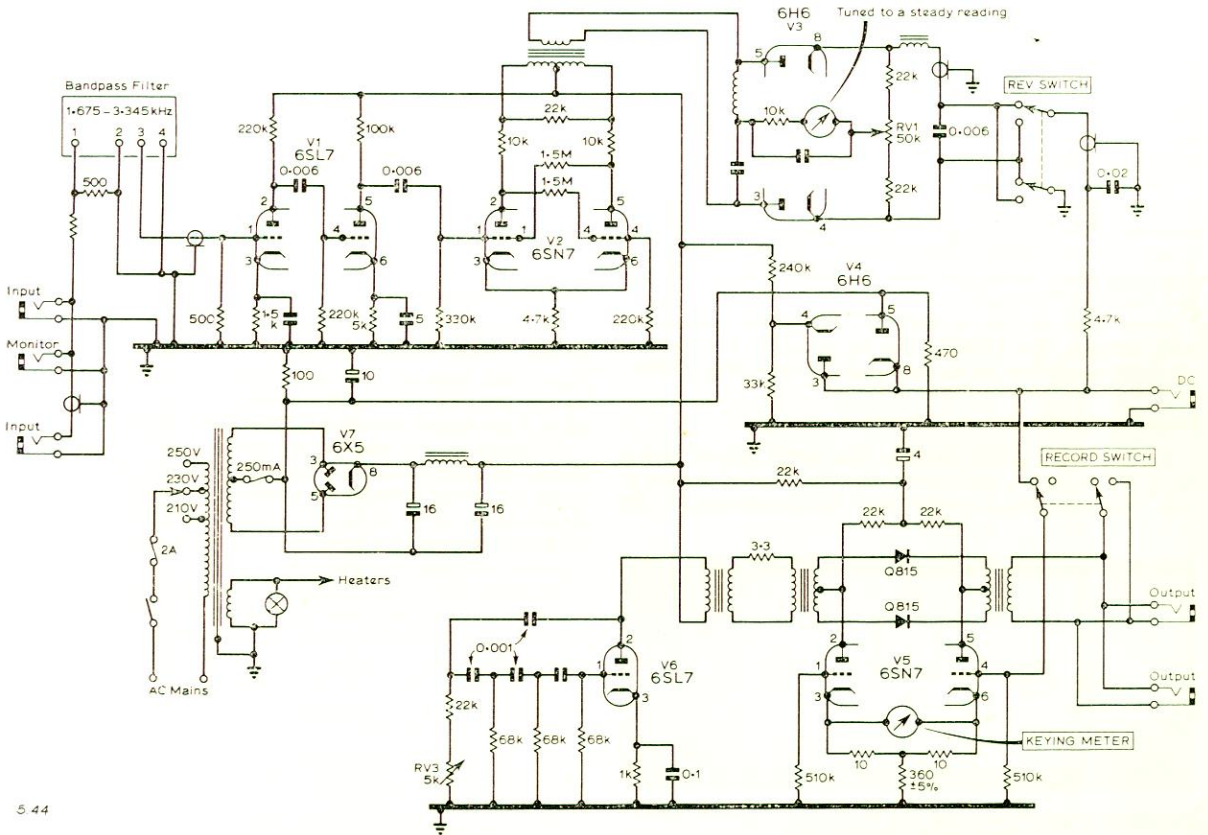
GCRE FS/10

Front panel view of the FS/10 demodulator for recording purposes. The circuit diagram is shown at Fig 5.44 below.



The FS/10 is a totally enclosed (with removable panels), self-contained unit with mains psu, standard rack mounting 19in × 5¼in × 11in and finished in black crackle. Front panel has an input meter (tune to steady reading),discriminator meter (mark–space) and all controls. Inputs and outputs can be taken from front or rear standard jacks. All valves are GT types.

The unit was designed for recording and it appears that there are at least two versions, one with transformer output and one with polar relay output. The polar relay fitted is a T.M.C. Carpenter Type 5A6CTR, a small plug-in type about 3in × 1½in × ¾in overall, and is used to key an internal phase shift oscillator, tone output 2·4–3·3Hz. As the unit follows audio TU circuitry, the relay contacts can be used, instead, to key a teleprinter loop in the normal way by disconnecting the leads to the tone generator. If this is done, it is essential to fit spark quenching and interference suppression components at the base of the relay. These can be 0·05μF capacitors and small rf chokes. An improvement would be to key the teleprinter magnet by a pair of 6V6 GT's, then the relay merely switches 100μA grid current, and contact life is prolonged appreciably. Room for the 6V6's may be obtained by replacing the 6H6's with OA81 semiconductor diodes.



5.44

The input bandpass filter, T.M.C.D.214066/1 has a pass band of 1,675–3,345Hz and is closely comparable with the filter used in the ATM TU's. However, as the monitoring jack in the FS/10 comes before the bandpass filter, it would be easy to plug in headphones and conclude that the unit is rather wide. All that the jack does is to monitor the receiver output (600Ω). 100mV is required for full limiting action, and shifts between 100Hz and 1,675Hz can be accommodated. The discriminator centre frequency is 2,550Hz.

MARCONI RECORDING UNIT, TYPE HU.11 (Fig 5.45, inset)

Can be used on fsk or on on-off telegraphy. The HU.11 merely needs to be fed with audio frequency signals from a receiver (600Ω), and connected to the selector magnets of a double-current (eg 7B) teleprinter via a series resistance. It has a built-in 80–0–80V loop supply, and it keys the loop electronically without a relay. To enable it to be used with receivers less stable than those in commercial use, a wideband discriminator is followed by RC coupling and a dc restorer, giving good fsk printing in spite of frequency drift up to 1,000Hz. It has no bandpass filter. The circuit uses nine valves. Morse undulators can be operated from a separate keyer output (up to 30mA) from the rear socket SK2 ("Low Res").

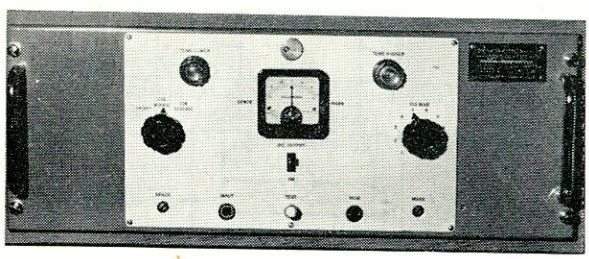
Mark and space tuning neons and a centre-zero loop current meter aid accurate tuning of the receiver. There is an efficient low-pass filter—and input S/N ratio of only 10dB still gives good printing. The third dc limiter valve selects and amplifies only a narrow, adjustable "slice" of the applied waveform, which helps to isolate noise from the keying circuits. As the edges of the pulses leaving the low-pass filter are slanting, the panel control that selects the "slice" acts also as a signal bias control.

The mains power supply is also included inside the neat two-tone grey cabinet, size 19¾in × 13in × 8in. Panel controls: "On/off keying", "fsk normal", "fsk reverse" switch. Mains on/off "Signal bias". "Test" button and mark/space loop-current pre-sets. Standard jacks for "input" and "monitor" phones.

Input level on fsk is between 20–25dBm. Frequency shift between 400–1,000Hz can be handled. Fsk output: 30–0–30 mA dc into an earthed load not exceeding 1,600Ω.

Installation

Receiver input (600Ω) either to front-panel "input" socket or to the two-pin socket above the top edge of chassis at rear. Teleprinters such as the Creed 7B are connected to the four-pin Painton socket SK1 ("High Res"), pin 3 goes to the earthy end of the 7B's selector magnet (pin 5 on the 7B's standard nine-pin plug), while pin 1 goes to the other end of the magnet (pin 3 of nine-pin plug) via a 4kΩ resistor. Ac mains (110/240V) goes to PL1 (line 3, neutral 1, earth 2 and 4).



The Marconi HU.11 recording unit. The circuit diagram is shown in the inset, which is Fig 5.45.

Setting Up

HU.11 "on", no signal input. Turn panel pre-sets mark and space fully anti-clockwise, "sig bias" to central position. Traffic switch to "fsk normal". Using "test" key, adjust mark and space pre-sets to give 20mA loop current either side of zero. Note that mark and space meter indications are for the Morse on/off convention, which are the opposite of those used in rtty.

RECEIVER ADAPTER OUTFIT ADMIRALTY PATTERN FAE (AT & E TYPE FSW) (Fig 5.46)

Introduction

This equipment is designed to accept frequency shift signals of (*a*) narrow, 10–200Hz centred on 600Hz and (*b*) wide, 150–1000Hz centred on 2,550Hz.

The outfit comprises a cabinet AP100370 (suitable for installation in a 19in rack) fitted with telescopic runners, housing four sub units mounted side by side. When viewed from the front they are: rectifier unit AP67925A design 140, limiter discriminator chassis AP103352, amplifier unit AP67950A design 8, rectifier unit AP67952A design 140. The cabinet is 24in deep with front panel 7in high.

Associated with the outfit FAE is the cathode ray frequency shift indicator AP67980A (described separately under test equipment).

The equipment accepts fsk signals at audio frequencies, these signals being filtered, amplified, limited and converted into dc pulses for the operation of single- or double-current teleprinters, no external relays or dc supplies being required.

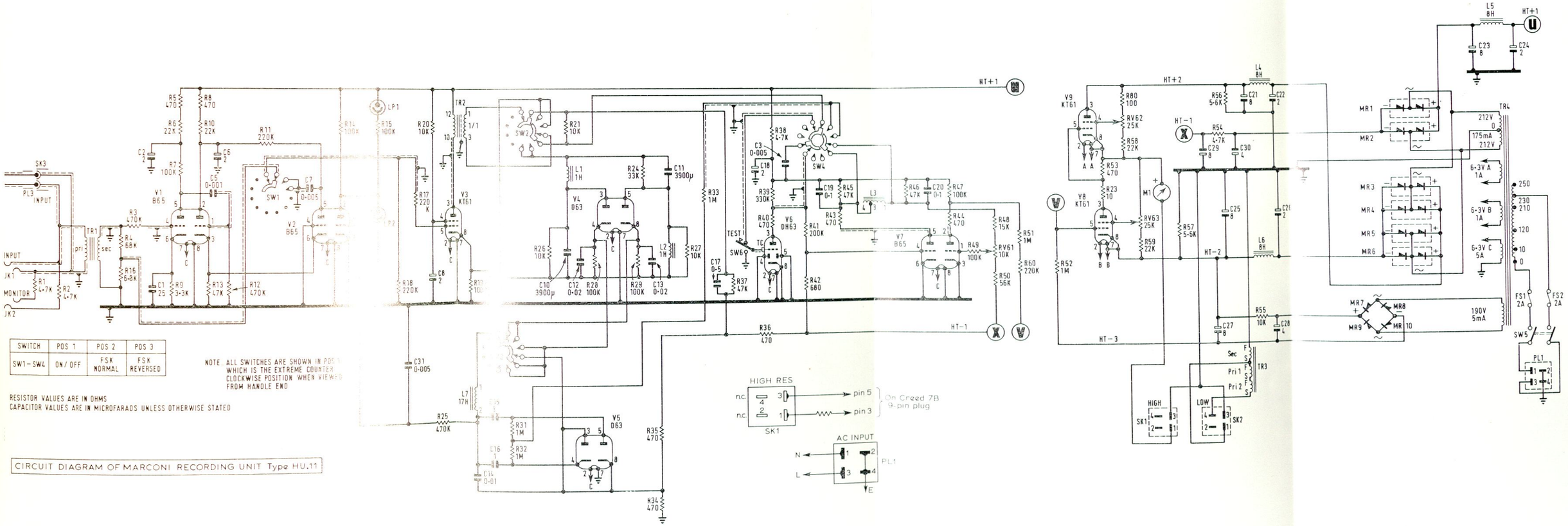
General Description

The rectifier units are identical but cable forms are so arranged that positive ht supply with respect to chassis is provided from one unit and negative ht is provided by the second unit. The first unit supplies 6·3V ac with respect to ht and the second provides 6·3V ac with respect to chassis.

Mounted at the rear of the cabinet are two bandpass filters, the appropriate filter for wide or narrow shift working being connected between the receiver output and the limiter discriminator by inserting input and output plugs into the sockets on the panel outside the rear of the cabinet. Characteristics are tabled in **Table 5.1**.

Separate plug-in discriminator networks are provided for wide or narrow shift, the required network being plugged into the limiter discriminator chassis. Efficient amplifying and limiting circuits present the discriminator with a reasonably constant signal level, allowing the equipment to successfully handle fsk signals having a carrier level variation from +10 to −85dBm, the frequency discriminating network having a substantially linear frequency/voltage response, thus permitting a wide range of transmitter shift to be accepted.

Manual bias adjustment is incorporated, permitting bias



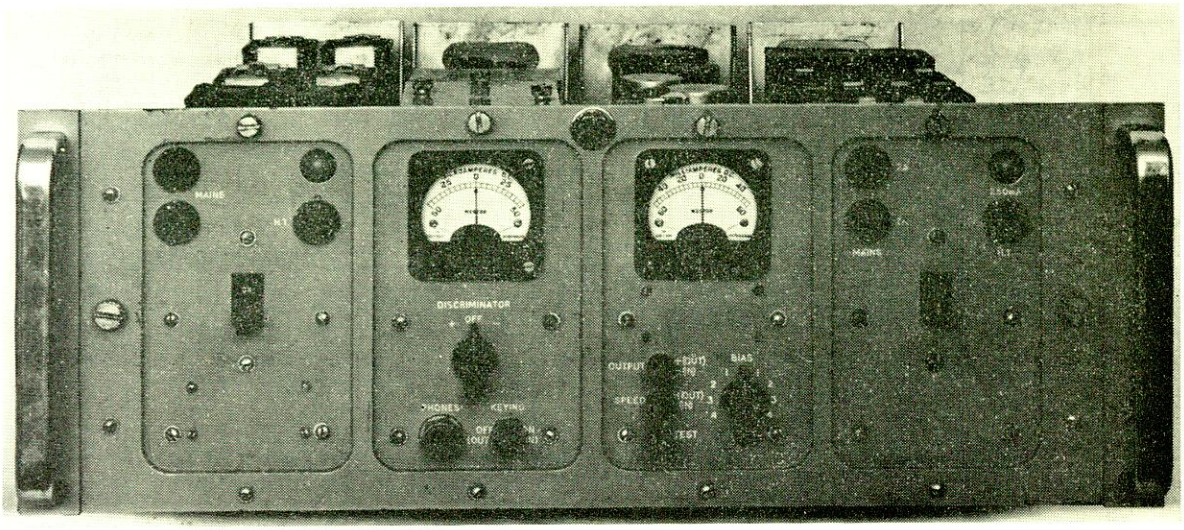
SWITCH	POS 1	POS 2	POS 3
SW1–SW4	ON/OFF	FSK NORMAL	FSK REVERSED

NOTE. ALL SWITCHES ARE SHOWN IN POS 1 WHICH IS THE EXTREME COUNTER CLOCKWISE POSITION WHEN VIEWED FROM HANDLE END

RESISTOR VALUES ARE IN OHMS
CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE STATED

CIRCUIT DIAGRAM OF MARCONI RECORDING UNIT Type HU.11

Fig 5.45



An FAE terminal unit. See overleaf for circuit diagrams (Figs 5.46-48).

distortion compensation, a headphone jack socket provides a monitoring facility after the tones have passed the input bandpass filters, inbuilt meters monitor single voltages and output currents.

Operation

1. Rectifier units, set switch S1 on both units to "on".
2. Limiter discriminator unit, set discriminator switch SA to "off".
3. Limiter discriminator unit, set keying switch SB to "on".
4. Amplifier unit, set double/single current switch S4, on top of chassis to "double current". Set output reversing switch S3 to normal (IN). Set bias control RV1 to zero. Set speed switch to low (IN). Adjust space current potentiometer RV3 on top of chassis to 25mA space current, or as required by teleprinter in use. Press test switch S1 and adjust mark current potentiometer for a mark current of 25mA or as required. Adjust the balance potentiometer RV4 on top of chassis, slowly clockwise until M1 reads zero, continue this adjustment until the amplifier just holds on the steady space condition. Check that the meter reading is reversed when the output reversing switch S3 is set to reverse (OUT).
5. If the teleprinter is designed for single-current working set switch S4 to "single current" and adjust the mark potentiometer RV2 to obtain the required current.
6. Switch the teleprinter on, set the discriminator switch SA to "on". Set the keying switch SB to "on". Assuming correct receiver tuning the teleprinter should be printing correctly.
7. Note, when the discriminator switch SA is set to "off" the output from the limiter is disconnected. When the discriminator switch SB is set to "off" the output from the limiter discriminator is disconnected and a potential is applied to the input of the amplifier unit simulating a mark signal. This holds the teleprinter in the idling condition.

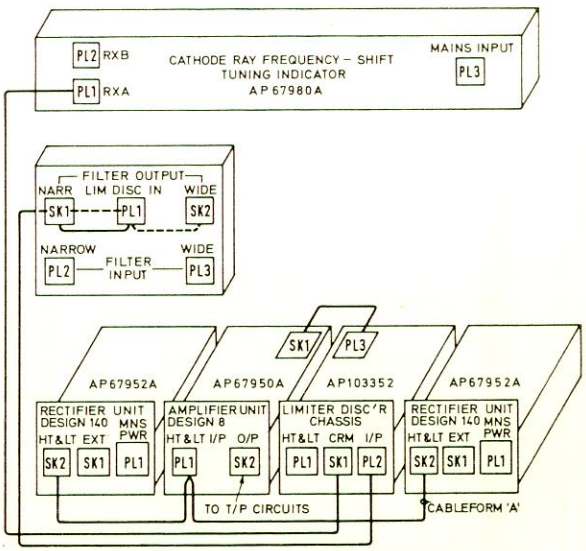


Fig 5.49. FAE, unit interconnection.

TABLE 5.1

Band pass filter characteristics		
Filter	**Response**	**Function**
1,700–3,450Hz AP101329	—40dB below 1,500Hz and above 3,800Hz	Frequency shift working, wide band, with discriminator centre frequency at 2,550Hz.
460–800Hz AP103368	—52dB below 300Hz and above 1,000Hz	Frequency shift working, narrow band, with discriminator centre frequency at 600Hz.

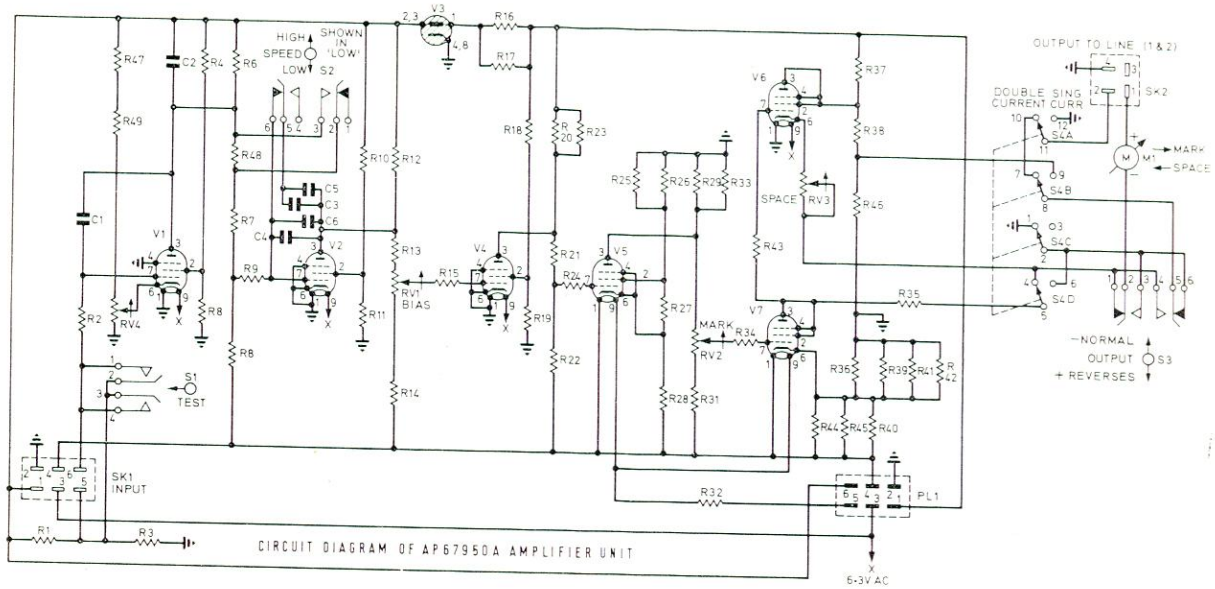


Fig 5.46. FAE, circuit diagram, AP67950A amplifier unit.

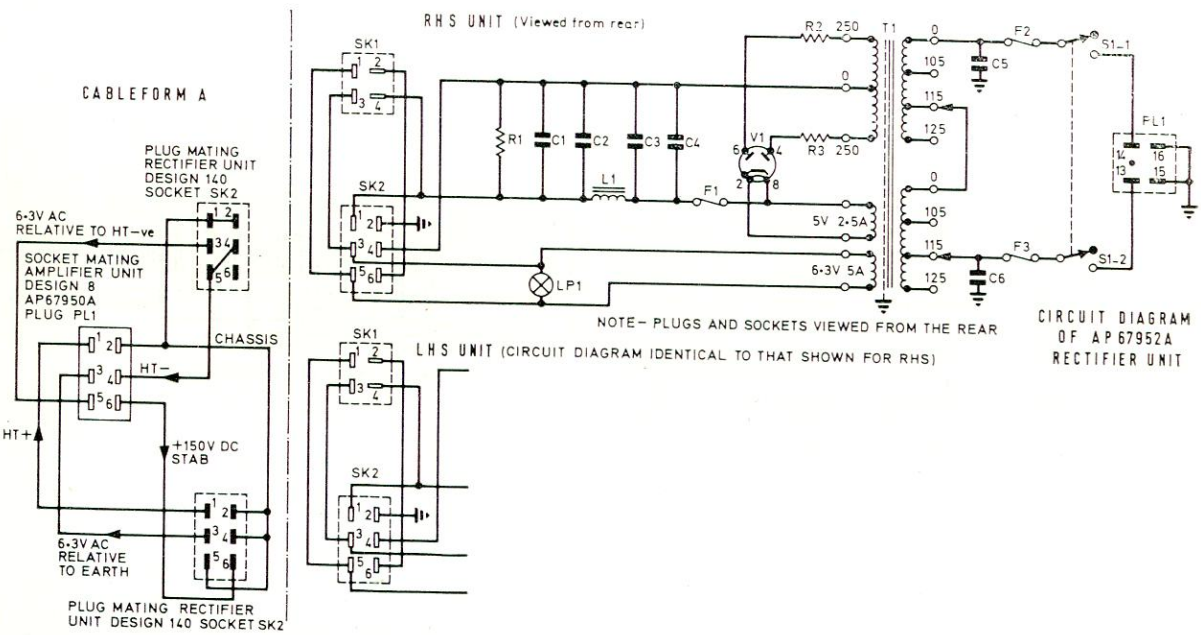

CABLEFORM A
PLUG MATING RECTIFIER UNIT DESIGN 140 SOCKET SK2
6·3V AC RELATIVE TO HT—ve
SOCKET MATING AMPLIFIER UNIT DESIGN 8 AP67950A PLUG PL1
CHASSIS
HT—
HT+
+150V DC STAB
6·3V AC RELATIVE TO EARTH
PLUG MATING RECTIFIER UNIT DESIGN 140 SOCKET SK2
RHS UNIT (Viewed from rear)
LHS UNIT (CIRCUIT DIAGRAM IDENTICAL TO THAT SHOWN FOR RHS)
5V 2·5A
6·3V 5A
NOTE— PLUGS AND SOCKETS VIEWED FROM THE REAR
CIRCUIT DIAGRAM OF AP67952A RECTIFIER UNIT

Fig 5.48. FAE, circuit diagram, AP67952A, rectifier unit.

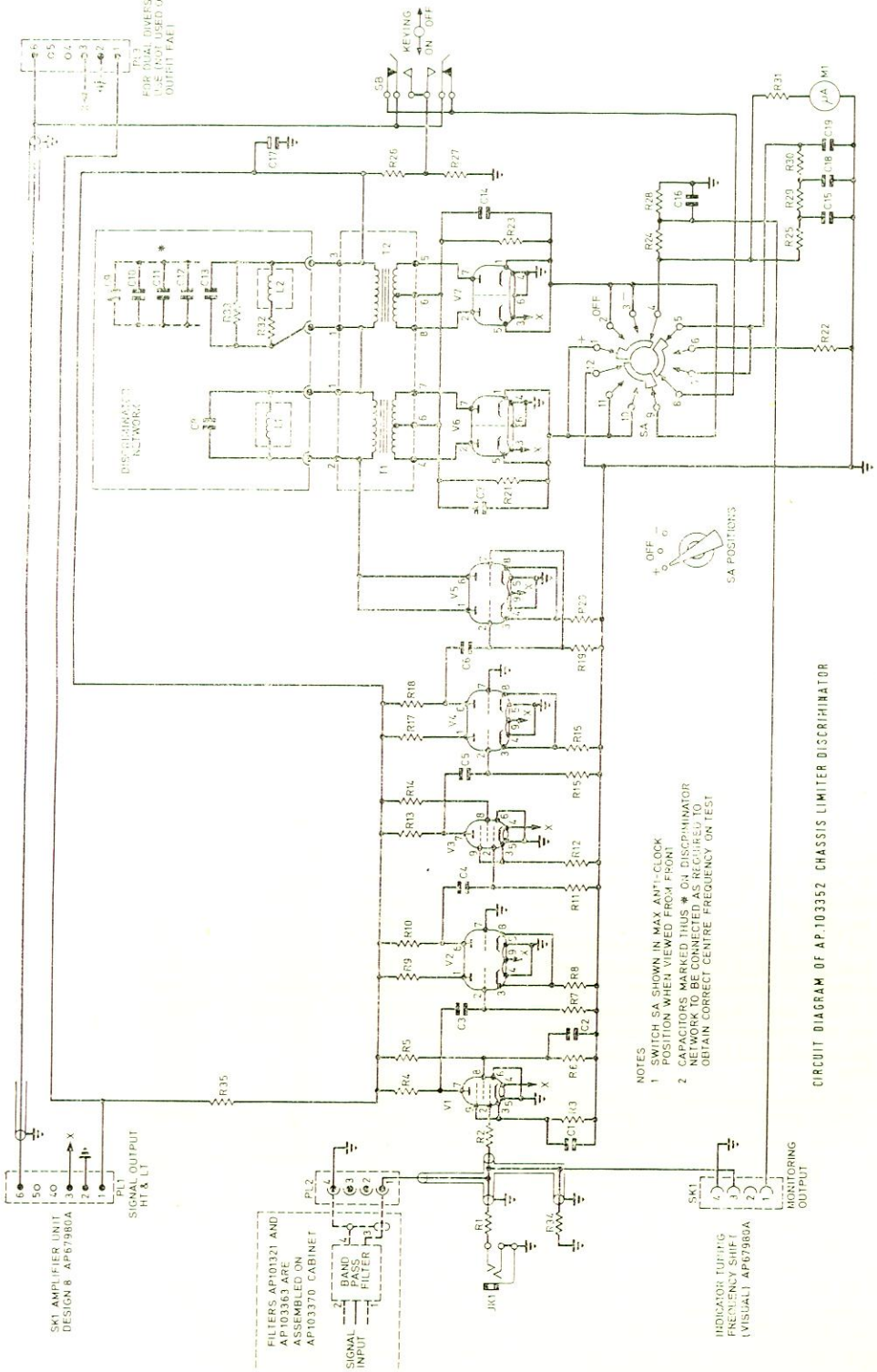

SK1 AMPLIFIER UNIT DESIGN B AP67980A
SIGNAL OUTPUT HT & LT
PL1
FILTERS AP101321 AND AP103363 ARE ASSEMBLED ON AP103370 CABINET
PL2
BAND PASS FILTER
SIGNAL INPUT
JK1
INDICATOR TUNING FREQUENCY SHIFT (VISUAL) AP67980A
SK1
MONITORING OUTPUT
PL3
FOR DUAL DIVERSITY USE (NOT USED ON OUTPUT FAE)
KEYING
ON
OFF
SB
M1
DISCRIMINATOR NETWORK
SA POSITIONS
NOTES
1 SWITCH SA SHOWN IN MAX ANTI-CLOCK POSITION WHEN VIEWED FROM FRONT
2 CAPACITORS MARKED THUS * ON DISCRIMINATOR NETWORK TO BE CONNECTED AS REQUIRED TO OBTAIN CORRECT CENTRE FREQUENCY ON TEST
CIRCUIT DIAGRAM OF AP.103352 CHASSIS LIMITER DISCRIMINATOR

Fig. 5.47. FAE, circuit diagram, AP103352 limiter discriminator.

Theory of Operation

Limiter Discriminator Chassis (Fig 5.47)

The signals from the output of the bandpass filter are applied to the grid of the first amplifier valve V1 via pins 1 and 4 of plug PL2 and a resistor R2 and to jack socket JK1 via resistor R1.

The amplified signals are applied to the grid of valve V2 which is a cathode coupled limiter. A second amplifier and cathode coupled stage, valves V3 and V4, amplify and limit the signal to further reduce the effect of fading on the input signal. The output stage, valve V5, is a double triode amplifier with the two halves strapped together.

The output from valve V5 is applied to two transformers T1 and T2 connected in series. The discriminator networks, which are of the plug-in type, are connected across the primary windings of these transformers and consist of two parallel tuned circuits, one tuned above and the other below the discriminating network centre frequency.

The output from the discriminator stage is applied via switch SA and a three-stage filter to switch SB. Meter M1 is a centre zero micro-ammeter which, in series with R31, is shunted across the output and indicates the dc voltage produced by the discriminator. In the "off" position, switch SA disconnects the discriminator output and inserts R22 between valve V1 grid and earth in the amplifier unit.

The output from the discriminator is applied to a two-position keying switch SB, which when set to the "on" position applies the discriminator output to the grid of V1 in the amplifier unit. In the "off" position switch SB disconnects the discriminator output from the succeeding stages and a dc potential, derived from the junction of R26-R27 in the ht line, is applied to the grid of V1 in the amplifier unit to simulate a mark signal.

Two discriminating networks are provided. One is centred at 600Hz for the reception of narrow-frequency transmissions, the second is centred at 2,550Hz for wide-frequency shift reception.

Amplifier Unit

The dc output signal from the limiter discriminator is applied to the grid of valve V1, the first of a series of dc amplifying stages consisting of V1, V2, V4 and V5, which in turn feed two output amplifiers V6 and V7. RV5 is connected to the cathode circuit of V1 and controls its operating point. The second stage V2 is an integrating amplifier limiter with a trapezoidal output waveform. Capacitor network C3, C4, C5, C6 is switched by S2. When operating on low-speed signals all four capacitors are connnected between the grid and anode of V2, but when operating on high speed signals only C4 and C6 are in circuit.

Potentiometer RV1 provides a bias control which adjusts the operating point of valve V4 relative to the reference level of the trapezoidal waveform. Valves V4 and V5 are amplifier-limiters. V5 drives the output amplifier V7 which in turn drives V6. Valves V5 and V7 operate with their heaters and cathodes at negative ht potential (300V negative to earth).

Potentiometer RV2 gives control of the negative signal output current and RV3 of the positive signal output current. The output is connected by switch S4, switch S3 and meter M1 to line. Switch S3 provides for reversal of the line connection in either setting of S4. Meter M1 indicates the outoing signal current. Switch S4 provides for single- or double-current working.

Manual test facilities are provided by means of a press switch S1. The output valves V6 and V7 are adjusted to give equal mark and space currents with potentiometers RV2 and RV3. In practice potentiometer RV4 is offset slightly so that with zero potential on the grid of V1 the output just holds in the space condition. With switch S1 closed, a positive dc potential derived from the 150V ht line via resistors R1–R3 is applied to the grid of V1, thus simulating a mark signal. Valve V3 is a neon stabilizer and in conjunction with resistors R16–R17 provides a stabilized 150V ht for valves V1 and V2 in the amplifier unit and valves V1, V2, V3, V4 and V5, on the limiter discriminator chassis.

FREQUENCY SHIFT ADAPTERS MODELS FSR 1.1 AND FSY 1.1

Introduction

The frequency shift adapters accept frequency shift signals at af, the signals then being filtered, amplified and converted to dc pulses which operate a high speed Carpenter telegraph relay. This in turn keys the battery dc supply for operation of the teleprinter or reperforator. A tuning indicator (indicator CRT Type 3 described under the chapter headed Test Equipment) is used to facilitate correct tuning of the receiver.

Circuit Description Type FSY 1.1

The adapters operate from a 600Ω unbalanced af input. A resistive T network R1, R2, R3, R5 and R6 is inserted to improve the matching of the bandpass filter over the required range of frequencies. This input filter has a passband of 1,700–3,500Hz and the attenuation of all frequencies below 1,500Hz and above 3,800Hz is greater than 40dB. The filtered mark and space input signals can be monitored by plugging headphones into the front panel jack.

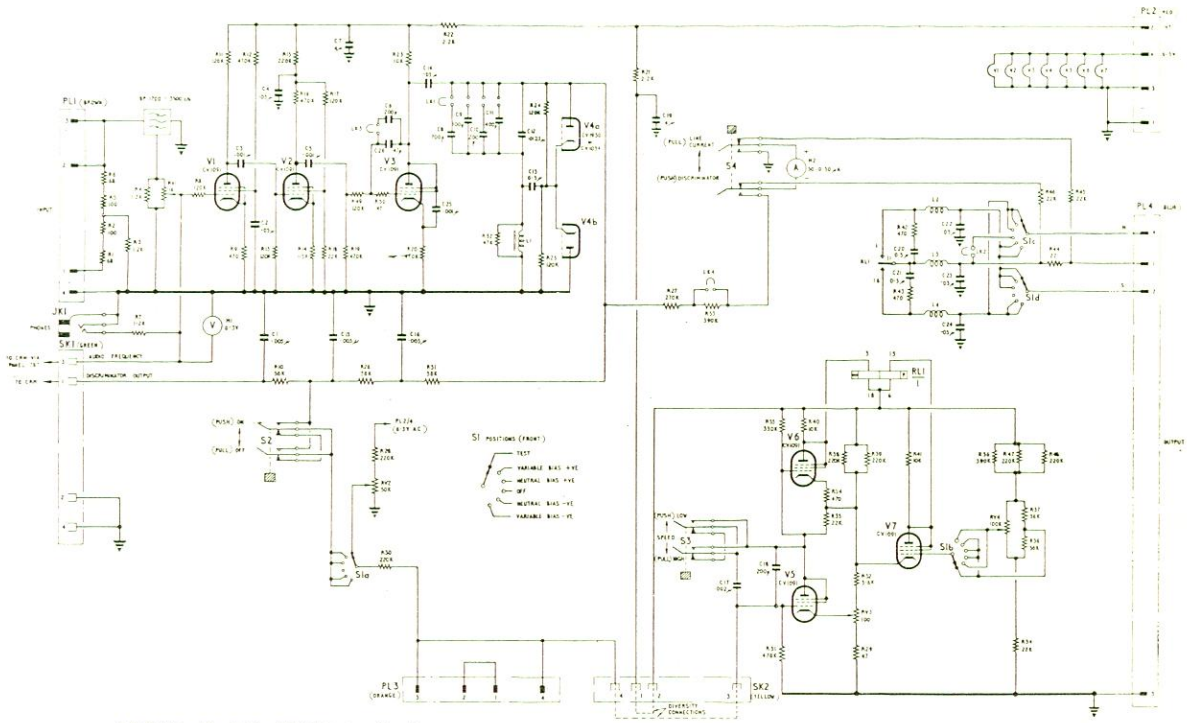
Carrier Amplifier-limiter

The frequency shift-carrier frequency band is amplified in a high gain non-linear amplifier, V1, V2 and V3. The first two valves are class A amplifiers and V3 is a triode connected pentode which limits the positive and negative going elements of the signal by grid current on the one hand, and anode bend cut-off on the other. Amplitude variations in the carrier signal are removed without producing telegraph distortion. Input variations of between −50dB and +20dB can be accepted.

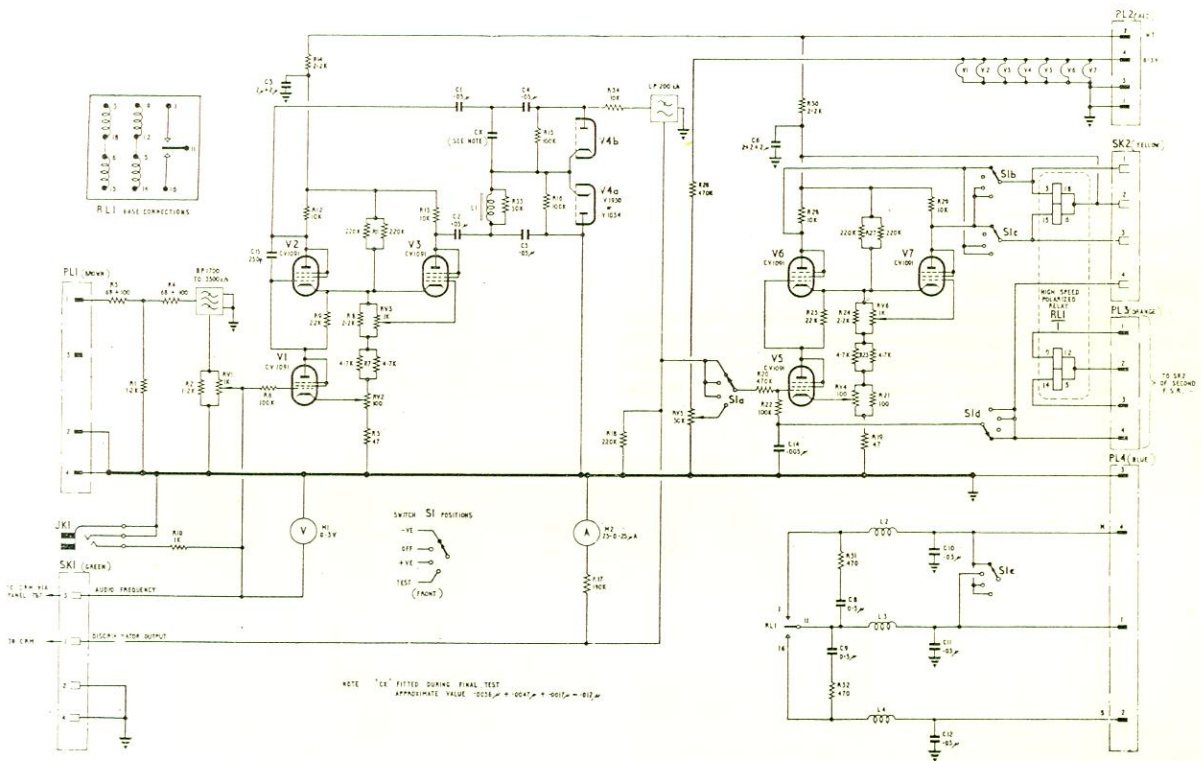
Demodulator

This is a two-branch discriminating network consisting of capacitor C12 and inductor L1 which have equal impedances at the carrier centre frequency of 2,550Hz. At any other frequency within the range of the input bandpass filter, the circuit becomes unbalanced and the output from the differential discriminator V4 will be positive for higher frequencies (space) and negative for lower frequencies (mark).

The balanced differential connection of this frequency discriminating network minimizes the response to pulse-type noise. The voltage/frequency curve of the discriminator is linearly centred at about 2,550Hz.



ABOVE: Fig 5.50. FSY1.1 circuit diagram.



BELOW: Fig 5.51. FSR1.1 circuit diagram.

Keying Amplifier Limiter

The three valves V5, V6 and V7, which are triode connected, form a high gain non-linear dc amplifier, which operates the Carpenter relay. To improve the signal-to-noise ratio and to remove residual af components valve V5 employs negative feedback. High-speed keying is received with plunger key S3 in the "high" position and at low speed an additional capacitor is connected in parallel with C18 by operating S3 to the "low" position. V5 anode is directly coupled to V6 grid and the two valves are series connected with respect to the ht supply. V7 is provided to balance the no-signal current of V6 in the relay windings, to give a push-pull output and to apply a mark or space bias to the current through the telegraph relay when required, to remove transmitted bias on the telegraph signal.

Plugs

PL1 brown, af input, pin 1 live, pin 4 earth.
SK1 green, connection to CRT unit, pin 3 carries filtered input signal, pin 1 carries signal after discrimination, pins 2 and 4 earth.
PL2 red, power, pin 2 ht, pin 4 heaters, pins 1 and 3 earth.
PL4 blue, output, 80V positive pin 2, 80V negative pin 4, pin 1 output from relay tongue.

Functional Switch

S1a, S1b, Swc and S1d are all ganged on a single control spindle with six positions as detailed below.

1. Test switch S1a connects mains frequency test pulses (derived from the heater line via R28) to the keying amplifier limiter where it should produce perfect 50Hz reversals of the relay armature.
2. Variable bias (when the marking current to line is positive).
3. Neutral bias (when the marking current to line is positive).
4. Off.
5. Neutral bias (when the marking current to line is negative).
6. Variable bias (when the marking current to line is negative).

FSR 1.1 Adaptor Unit

Carrier amplifier limiter—the carrier frequency is amplified in a transient free high gain non-linear cascade dc amplifier. This consists of valves V1, V2 and V3 connected as triodes. The amplifier limiter has an essentially square wave output with transitions coinciding with the passage of the instantaneous voltage of the carrier signal to zero. Variations of 60dB in the input signal can be accepted. Since V3 is cathode coupled to V2 it acts as a para-phase amplifier producing a negative going wave form at its anode. The push pull output of V2, V3 is applied to the discriminator circuit L1 Cx. The two valves V2, V3 ensure a balanced input to the discriminator, balance being achieved by adjustment of RV2 and RV3.

Demodulator

The linear demodulator V4 is fed by a two-branch discriminating network similar to that used in the FSY unit.

Low-pass Filter

The low-pass filter following the demodulator improves the signal to noise ratio by removing the residual af components in the waveform. This filter has a cut off frequency of 150Hz and consists of two sections giving a minimum attenuation of 38dB at frequencies of 200Hz and above.

Keying Amplifier Limiter

The three valves V5, V6 and V7 comprise a cascade non-linear dc amplifier limiter for operating the telegraph relay. Variations in the amplitude of dc pulses from the demodulator have no effect on the keying current waveform shape. A drift of the centre frequency of the carrier signal of up to ±350Hz using 850Hz produces a distortion of less than 2 per cent. The sensitivity of V5 is adjusted by bias control RV4.

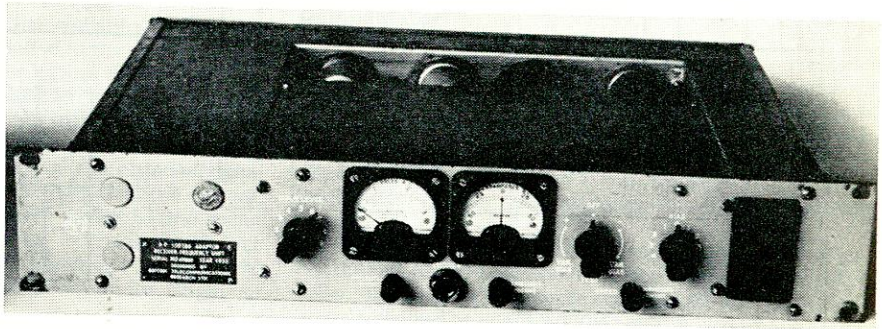
Output

Valves V6 and V7 provide a push-pull output as in the FSY unit.

Functional Switch

Five rotary switches are ganged to a single control spindle with four positions.

1. Switch S1a connects the keying amplifier to the demodulator for the reception of signals or to the heater supply for mains frequency test voltage.
2. Switches S1b and S1c provide for the reversal of polarity of mark and space.
3. Switch S1d joins the control grids of valves V5 in all positions except off. Switch S1e is not used.



The FSY 1.1 frequency shift adaptor.

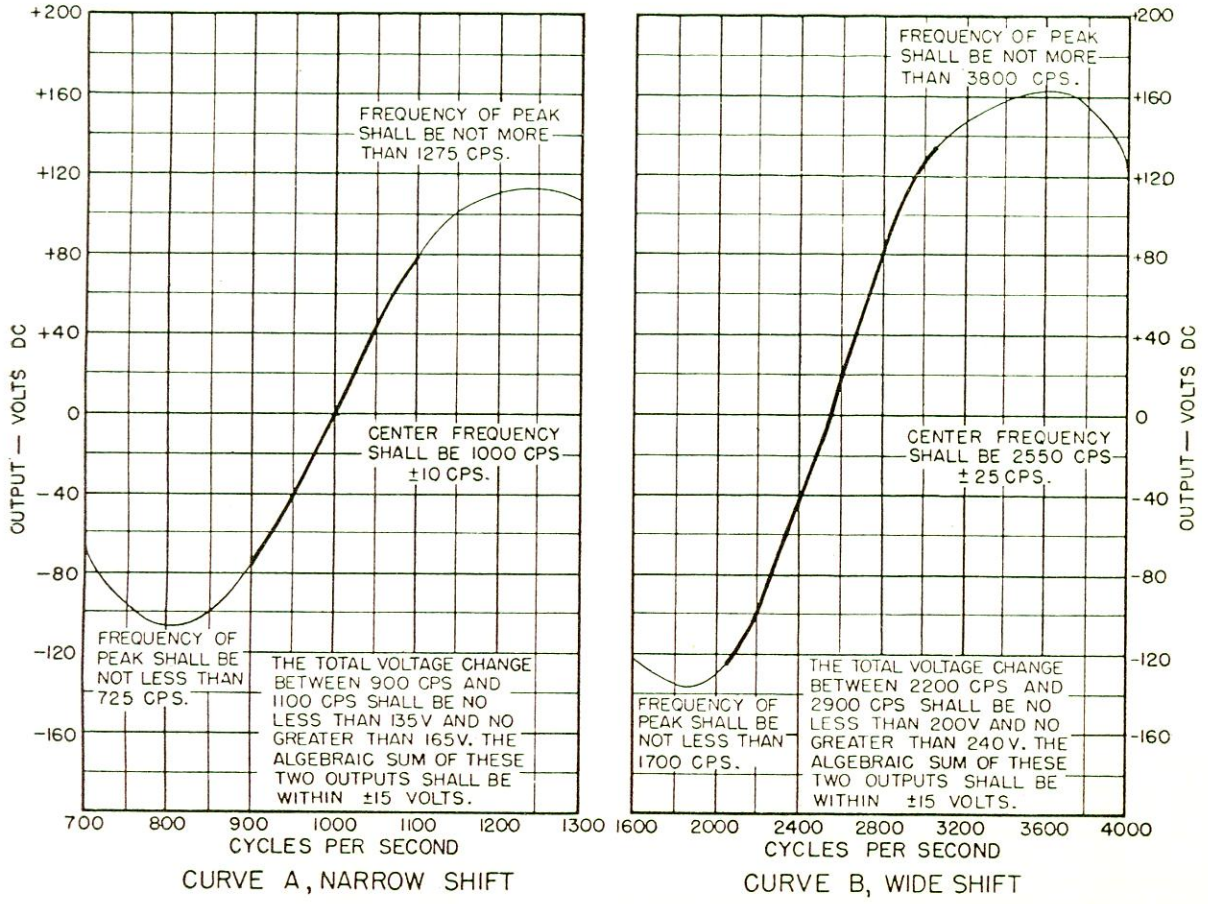

+200
+160
+120
+80
+40
0
-40
-80
-120
-160
OUTPUT — VOLTS DC
FREQUENCY OF PEAK SHALL BE NOT MORE THAN 1275 CPS.
CENTER FREQUENCY SHALL BE 1000 CPS ±10 CPS.
FREQUENCY OF PEAK SHALL BE NOT LESS THAN 725 CPS.
THE TOTAL VOLTAGE CHANGE BETWEEN 900 CPS AND 1100 CPS SHALL BE NO LESS THAN 135V AND NO GREATER THAN 165V. THE ALGEBRAIC SUM OF THESE TWO OUTPUTS SHALL BE WITHIN ±15 VOLTS.
700 800 900 1000 1100 1200 1300
CYCLES PER SECOND
CURVE A, NARROW SHIFT
FREQUENCY OF PEAK SHALL BE NOT MORE THAN 3800 CPS.
CENTER FREQUENCY SHALL BE 2550 CPS ±25 CPS.
FREQUENCY OF PEAK SHALL BE NOT LESS THAN 1700 CPS.
THE TOTAL VOLTAGE CHANGE BETWEEN 2200 CPS AND 2900 CPS SHALL BE NO LESS THAN 200V AND NO GREATER THAN 240V. THE ALGEBRAIC SUM OF THESE TWO OUTPUTS SHALL BE WITHIN ±15 VOLTS.
1600 2000 2400 2800 3200 3600 4000
CYCLES PER SECOND
CURVE B, WIDE SHIFT

Fig 5.52. CV89 discriminator frequency response curves.

Power Unit Type 761

This power supply unit is used with both FSY and FSR adaptor units and is of conventional design. The input transformer has tappings of 210V, 230V and 250V. This transformer provides 250/0/250 which is rectified by V1. A conventional two stage capacitor input filter is used for smoothing. Voltmeters and milliammeters are provided for ht measurements. Sufficient output is available to operate two adapter units, and the ht supplies to the two units via terminals 2 on sockets SK3 and SK4 are fused by 250mA fuses F1 and F2. Terminals 1 of these sockets carry the ht negative line, terminals 4 the heater supply and terminals 3 are earthed.

THE CV.89 FREQUENCY SHIFT CONVERTER (Fig 5.53 inset)

The CV.89 Frequency Shift Converter is one of three units contained in the AN/URA8 Frequency Shift Converter Comparator Group. The group consists of two CV.89's and one Comparator CM.22A. For diversity reception, the output of each receiver is connected to one of the two converter units and the dc signals from the discriminator circuits are fed to the comparator. The comparator compares the two signals in a circuit which automatically selects the better mark and better space pulse for each character.

The frequency shift converters may be used separately for single receiver reception, each converter having its own output circuits for keying the printer dc loop (single current) and providing a keyed audio tone. The units are capable of receiving frequency shifts of between 10–2,000Hz in two ranges.

Circuit Description

(a) Discriminator Sub-unit (SU101)

1. *Input Filter.* The input filter of Converter CV.89A/URA.8A is composed of two separate filters, a high-pass filter, Z101, and a bandpass filter, Z102. Each filter is connected to a separate af input through three sections of the narrow-wide shift switch, S101. The purpose of these filters is to eliminate the possibility of false keying in the converter by extraneous signals at frequencies outside the frequency-shift range being used.

The high-pass filter, Z101, is used for the reception of narrow frequency-shift signals and has an input impedance of 600Ω ohms. This filter is flat (±1dB) from 775–1,400Hz, and down to not less than 40dB at 425Hz and below.

The bandpass filter, Z102, is used for the reception of wide frequency-shift signals and also has an input impedance of 600Ω. The passband of this filter is within 6dB from 1,450–3,650Hz, and the attenuation is 40dB or better at frequencies of 1,000Hz and below and 4,100Hz and above.

The output of the input filter is coupled to the limiter amplifier by the matching transformer, T101, through one section of the narrow-wide shift switch, S101A.

2. *Limiter Amplifier*. The limiter amplifier consists of two resistance coupled stages, each stage employing one half of a 12AX7 high-mu twin triode, V101. This limiter is designed to apply a constant voltage to the input circuit of the discriminator with variations of input to the limiter amplifier from 60μW to 60mW.

In the first stage of the limiter amplifier the bias voltage that is obtained from the voltage divider, R104 and R105, is midpoint between the zero grid voltage point and the grid bias cut-off point. The signal limiting on the positive peaks is obtained by rectified grid current through the series grid resistor, R103, and on the negative peaks by cut-off bias.

The second stage of the limiter amplifier functions in the same manner as the first limiter stage except that it is operating at a higher level.

The output of the limiter amplifier is coupled to the input of the discriminator circuit by the coupling capacitor, C102, through one section of the narrow-wide shift switch, S101B.

3. *Discriminator*. The discriminator circuit is essentially a two-slope back-to-back detector consisting of three sections: the discriminator input network, the discriminator buffer amplifier, and the discriminator rectifier. The purpose of the discriminator circuit is to convert frequency-shift changes into corresponding dc voltages.

(*a*) Discriminator Input Network: Two separate discriminator input networks are employed, Z103 and Z104, one for narrow frequency-shift operation and the other for wide frequency-shift operation.

The narrow frequency-shift network, Z103, is composed of two separate filters having a cross-over or centre frequency of 1,000Hz, ±1 per cent, and are designed to cover the 10–200Hz frequency-shift range. One filter is tuned to 200Hz higher than the centre frequency and the other is tuned to 200Hz lower than the centre frequency. The response curves of these two filters overlap in such a way that when used in the complete discriminator circuit, the resulting dc output versus frequency input of the discriminator is as shown in the curve A of **Fig 5.52**.

The frequency-shift network, Z104, is also composed of two filters and has a cross-over or centre frequency of 2,550Hz, ±1 per cent. It is designed to cover the 200–1,000Hz frequency-shift range. One of these filters is tuned to 750Hz higher than the centre frequency and the other is tuned to 750Hz lower than the centre frequency. The curves of these two filters also overlap and produce the frequency response curve for the complete discriminator shown in B of **Fig 5.52**.

The output of the two discriminator network filters is connected to the grids of the two triodes of the discriminator buffer amplifier through two sections of the narrow-wide shift switch, S101B.

(*b*) Discriminator Buffer Amplifier: The discriminator buffer amplifier consists of two separate low-gain amplifiers, one for each side of the circuit, each employing one half of a 12AU7 tube, V102A and V102B. The grid of V102B is driven by the output from the lower frequency output terminal of the discriminator input network (pin 1 of Z103 or Z104) and the grid of V102A is driven by the higher frequency from the other output terminal (pin 4). Thus, one stage is amplifying the higher frequency output of the discriminator input network and the other stage is amplifying the low frequency output. The output of these buffer amplifiers is transformer-coupled to the discriminator rectifiers by two transformers, T102 and T103. T102 and T103 are conventional audio transformers, which pass all the frequencies involved in the discriminator operation. R110, R111 and R112 furnish the proper bias for both halves of the buffer amplifier.

(*c*) Discriminator Rectifier: The discriminator rectifier consists of two rectifiers, each employing one half of a 6AL5W duodiode. One diode, V103B, functions to rectify the low frequency output of the buffer amplifier and the other diode, V103A, functions to rectify the high frequency output. The dc voltage at the output terminals of the rectifier will vary in polarity and magnitude corresponding to the differences in the audio input to the rectifier. The dc output of the rectifier is delivered to the fast and slow speed low-pass filters through the reversing switch S102 and fast-slow filter selecting switch S103.

4. *Fast-slow Speed Filter*. The fast-slow filter consists of two separate low-pass filters, a slow-speed filter, Z105A, and a high-speed filter, Z105B. These attenuate spurious signals above the frequency of the pulse-rate of the circuit, to prevent faulty keying action due to noise, harmonics, etc.

The high-speed filter, Z105B, is employed for keying speeds of 60 words per minute or more and is flat (within 6dB) from 80–300Hz. The attenuation of this filter is 40dB or more at 500Hz and above.

The slow-speed filter, Z105A, is employed for keying speeds of 60 wpm or less and is flat (within 6dB) from 80–140Hz. This filter is down 40dB or more at frequencies of 240Hz and above.

The output of the high- and low-speed filter is delivered to the axis restorer and lock-up circuit through one section of the fast-slow switch, S103.

5. *Axis Restorer and Lock-up Circuit:* The axis restorer circuit is included to produce the optimum signal output when the received signal is weighted heavily on one side or the other, either mark or space, and to maintain the optimum axis, or bias, for keying the weakest portion of a fading signal. The weighting of the signal may be due to the relative mark and space in each character, to selective fading conditions, or to mis-tuning of the receiver. The axis restorer also contains a system which "locks-up" the teleprinter circuit (closing the loop circuit) whenever there is a prolonged mark, space, or no-signal condition. V104A and V104B and V105A and V105B are the tubes in this circuit.

When no signal is received by the converter, either mark or space, the circuits of V104A and V104B and V105A and V105B come to rest with a small positive voltage at the output of the circuit, the outer end of R120, which is applied through the inter-sub-unit wiring and S202 to the grid of V201B. This positive voltage produces a mark-signal output from the keyer and output circuits. The level of this voltage is adjusted by the threshold control R122 by adjusting the plate supply voltage to the axis-restorer's dc amplifier,

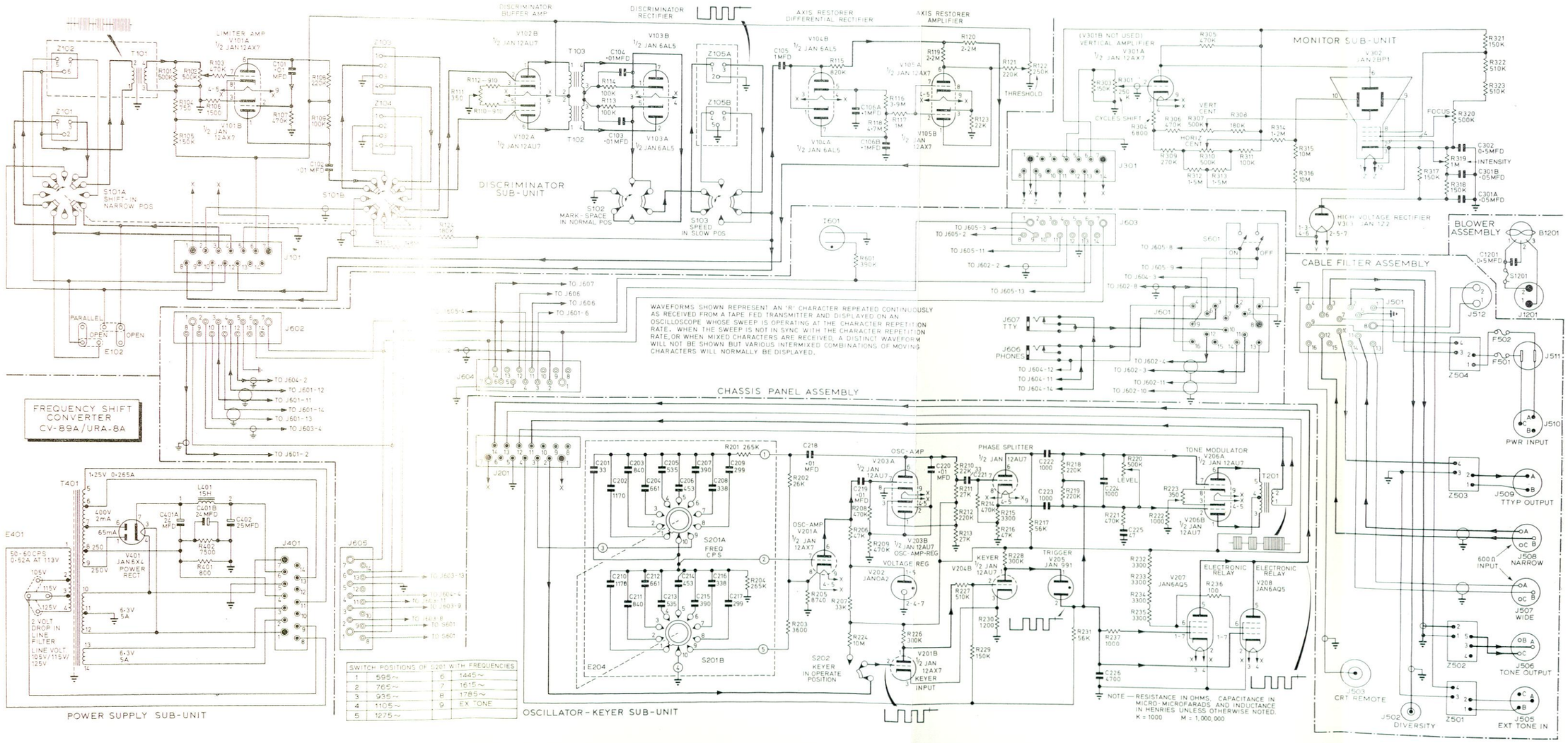

FREQUENCY SHIFT CONVERTER CV-89A/URA-8A
POWER SUPPLY SUB-UNIT
OSCILLATOR-KEYER SUB-UNIT
DISCRIMINATOR SUB-UNIT
CHASSIS PANEL ASSEMBLY
MONITOR SUB-UNIT
CABLE FILTER ASSEMBLY
BLOWER ASSEMBLY
WAVEFORMS SHOWN REPRESENT AN "R" CHARACTER REPEATED CONTINUOUSLY AS RECEIVED FROM A TAPE FED TRANSMITTER AND DISPLAYED ON AN OSCILLOSCOPE WHOSE SWEEP IS OPERATING AT THE CHARACTER REPETITION RATE. WHEN THE SWEEP IS NOT IN SYNC WITH THE CHARACTER REPETITION RATE, OR WHEN MIXED CHARACTERS ARE RECEIVED, A DISTINCT WAVEFORM WILL NOT BE SHOWN BUT VARIOUS INTERMIXED COMBINATIONS OF MOVING CHARACTERS WILL NORMALLY BE DISPLAYED.
SWITCH POSITIONS OF S201 WITH FREQUENCIES
1 595~
2 765~
3 935~
4 1105~
5 1275~
6 1445~
7 1615~
8 1785~
9 EX TONE
NOTE — RESISTANCE IN OHMS, CAPACITANCE IN MICRO-MICROFARADS AND INDUCTANCE IN HENRIES UNLESS OTHERWISE NOTED. K = 1000 M = 1,000,000

Fig 5.53. Circuit diagram, CV89, AN/URA-8B.

V105A and V105B. The two triodes of V105 are in parallel, acting as one triode. There is also positive voltage at one plate and one cathode, pins 1 and 2, of V104A and V104B, which, due to the conductivity of the V104B diode in this direction, charges C106A to this voltage. Later, through R116 and R118, C106B is also charged to the same level. This positive voltage is applied to the grids of V105A and V105B, and, with the cathode bias developed by R123, forms its at-rest bias. The bias, in turn, determines the positive voltage in the circuits just discussed by controlling the plate current of V105A and V105B and establishing the drop in its plate resistor R121.

When a symmetrical, evenly-weighted signal comes through C105 from the discriminator filter circuit, the diode of V104B rectifies the positive pulses, and V104A rectifies negative. The charges on C106A and C106B are thus equally displaced in opposite directions. Due to the difference or unbalance between R116 and R118 there is a small shift to more-positive on V105A and V105B grids, which in return reduces the positive lock-up voltage delivered to the keyer.

The proper setting of R122, threshold, for a low-level symmetrical signal will produce a bias, or operating axis, at V201B grid which gives the optimum keying. It is the purpose of the axis restorer to maintain this optimum axis for non-symmetrical signals.

At the grid of V201B a positive voltage of approximately 1V or more is required to swing the flip-flop keyer to key a mark signal. It will remain on mark until a negative voltage of approximately 1V or greater is applied whereupon it flips over to key a space signal. It will, in turn, remain on space until flopped back to mark by a positive voltage. The optimum keying axis will depend upon signal strength, noise conditions, etc. On strong, noise-free signals the axis setting is not critical, but on weak signals or on the weak portion of fading signals a careful setting is important. Under noise conditions the axis must be set enough positive that negative peaks of noise signal will not key.

The signal pulses from the discriminator pass through R115 and R120 to reach V201B. The grid of V201B is prevented from being driven excessively positive by the drop in R120 when the grid circuit conducts.

When a non-symmetrical signal, which has more and/or higher positive pulses (mark) than negative, passes through the system, the tendency would be for the bias axis to average in a positive direction away from the optimum value if it were not for the action of the axis restorer. The excess positive is rectified by V104B, charging C106A relatively more positive. This change is reflected through the resistor network to V105A and V105B which counteracts the change in the axis and, due to the amplification of the tube, essentially restores the bias to that occurring with a symmetrical signal.

A signal that is largely space characters would tend to move the axis negative but the axis restorer holds the axis practically at the symmetrical signal condition.

Since only the ac component of the signal reaches the axis restorer circuit from the discriminator, a prolonged mark signal, a prolonged space signal, and a no-signal condition appear the same to the axis restorer, except for the abrupt change at the beginning of the mark or space signal. A mark signal keys a mark output, and so a prolonged mark signal will leave the circuit in the mark or no-signal "lock-up" condition. A space signal keys a space output, and so a prolonged space signal will start as a space output and then shift over momentarily to the normal no-signal "lock-up" condition.

The time of the "lock-up" action varies with the setting of the threshold control, R122, and with the operating conditions. It will range from instantaneous "lock-up" to a possible condition where two or three seconds are required to "lock-up" from a strong continuous space signal. The time constant for any one condition is determined by all the components in the axis restorer circuits.

(b) Oscillator-keyer Sub-unit (SU201)

1. *Audio Oscillator-amplifier.* In this circuit V201A and V203A are used in a resistance-coupled audio amplifier which is made to oscillate by the use of positive feedback in the network between the output of V203A and the input of V201A. The positive and negative feedback network is designed in the form of a Wien bridge and is a frequency-selective resistance-capacity combination which allows one frequency to be applied to the grid of V201A in the proper phase and amplitude for oscillation. This frequency of oscillation is determined by the values of the components in the Wien bridge network. The parallel combination of R204 and the condensers switched by S201B form a parallel leg of the bridge network while R201 in series with the capacitors switched by S201 forms the series leg of the network.

In order to provide for good waveform the net amplification of the two oscillator tubes is kept low by introducing a fairly large degree of negative feedback together with the positive feedback used to provide oscillation. The negative feedback loop consists of R202 and the cathode resistor of V201A, R205.

V203B is connected as a diode which rectifies signals greater than the level established by the bias on the cathode of V203B, and applies this rectified voltage to the grid of V203A as bias. This stabilizes the output level of the osillator.

This oscillator-amplifier is tuneable to the following frequencies: 595Hz, 765Hz, 935Hz, 1,105Hz, 1,275Hz, 1,445Hz, 1,615Hz and 1,785Hz, by switching the capacitors in the two legs of the Wien bridge network. This is accomplished by switching the FREQ-CPS switch, S201, to positions 1 through 8 respectively. When in position 9, the FREQ-CPS switch allows an external tone to drive the grid of V201A and the oscillator-amplifier functions as a two stage resistance-coupled amplifier.

V202 is an OA2 regulator tube which regulates the voltage applied to the plate of the first oscillator tube V201A. This OA2 holds the voltage to within 2V of its working voltage (approximately 150V). The output of the audio oscillator-amplifier is capacitively coupled by C221, to the grid of the phase splitter stage.

2. *Phase splitter.* V204A is connected in a conventional phase splitter circuit to supply push-pull input to the grids of the tone modulator. The output from the cathode of V204A is capacitively coupled by C223 to the grid of V206B and the output from the plate of V204A is coupled to the grid of V206A by the capacitor C222.

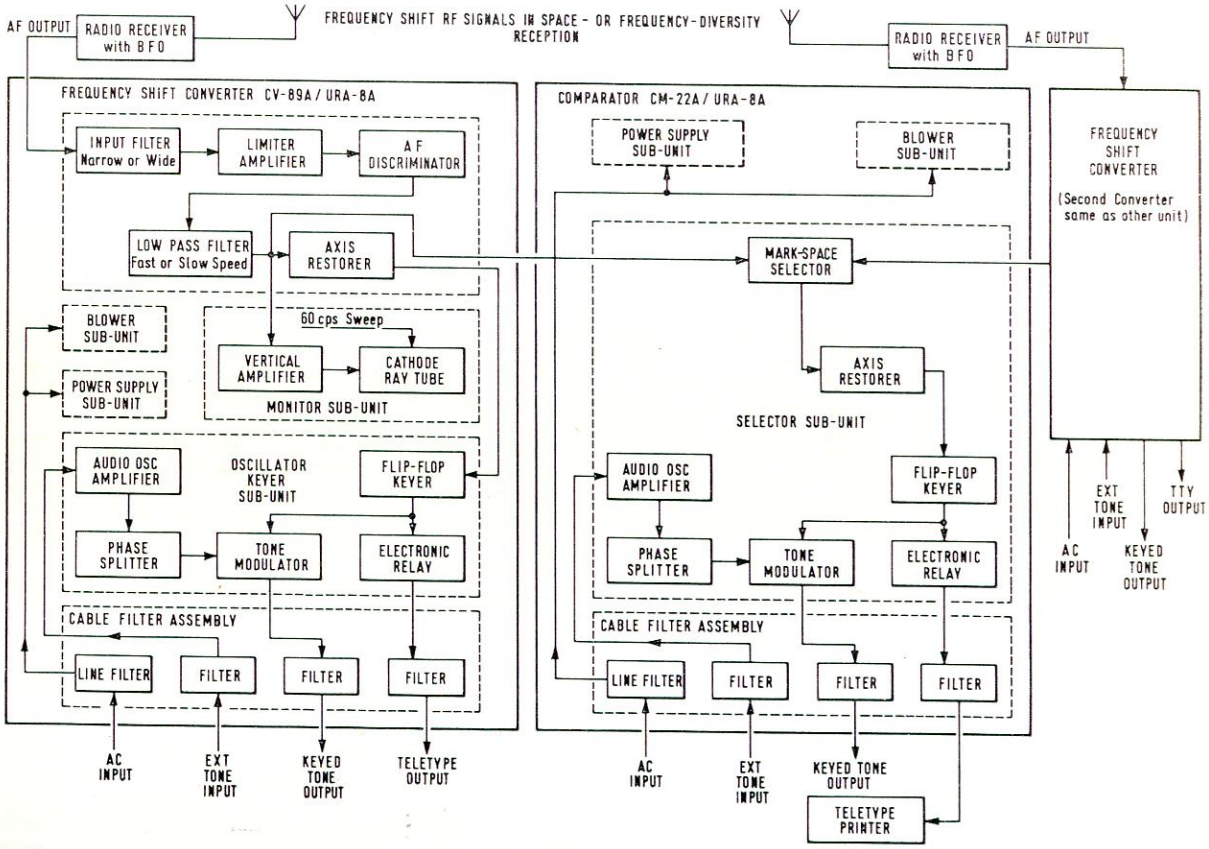
3. *Tone Modulator.* The tone modulator, V206, is a conventional push-pull audio output amplifier employing a 12AU7 twin triode. The output of the tone modulator is keyed from "tone on" to "tone off" by a high negative bias applied to the grids of the tone modulator V206A and V206B,

from the keyer circuit. This negative keying voltage drives the grids of the modulator tube to approximately two times cut-off, which results in no-tone output. The output of the tone modulator is transformer coupled by T201 through the filter Z502 to the tone output receptacle, J506.

4. *Keyer.* The keyer is a flip-flop circuit employing two triodes and a small neon tube. They are: V201B, one half of a 12AX7 twin triode; V204B, one half of a 12AU7 twin triode; and V205, a 991V regulator. V205 is used in the keyer circuit for triggering the flip-flop action. The action of this circuit under the "mark" condition is as follows: a normal mark signal is a positive voltage of about 1V, or higher, from the discriminator or from the axis restorer "lock-up" circuit. When this is applied to the grid of V201B, it causes the triode to conduct heavily. This causes a large voltage drop across R226 and across R230. The triode of V204B is then biased beyond cut-off because of the negative voltage reaching the grid through R229, and the positive on the cathode from the drop across R230. V204B will not conduct and thus allows full B+ to reach V205 through R228. This ionizes the neon gas, and V205 suddenly conducts current through R228 and R231. This causes a voltage drop across R231 of approximately 37V which is of opposite polarity to that of the negative 38V applied to R231 and results in a total of approximately 1V negative at the output of the keyer circuit. Under this condition the tone modulator is biased as an amplifier and the electronic relay is conductive. This results in "tone on" or tone output from the tone modulator, and allows the electronic relay to conduct the dc loop current that energizes the printer.

The action of the keyer circuit under the "space" condition is as follows: a normal space signal (about 1V or more negative) applied to the grid of V201B from the discriminator will cause V201B to draw less current. As V201B draws less current the voltage drop across R226 becomes smaller and allows the grid of V204B to become less negative. V204B now starts to conduct and due to the common cathode coupling between V201B and V204B the cathode of V201B becomes more positive which causes V201B to stop conducting. When V204B starts to conduct a greater voltage drop is developed across R228 which reduces the voltage at the trigger tube. This causes the ionization of the trigger tube V205 to be suddenly quenched and it stops conducting, which means there will be no drop across R231 to cancel out the negative bias. Thus the negative 38V is applied to the grids of the tone modulator and the electronic relay biasing them beyond cut-off. Under this condition both the tone modulator and the electronic relay block the passage of plate current or signal, resulting in "tone off" or no-tone output from the tone modulator and causing the electronic

Fig 5.54. Block diagram of URA-8.



relay to open the dc loop circuit that energizes the teletype printer.

When the input to V201B is swung from approximately 1V positive to 1V negative, or wider, the keyer produces sharply squared-off output pulses producing sharply defined characters at the output of the unit.

5. *Electronic Relay.* The electronic relay, consisting of two 6AQ5 pentodes, V207 and V208, is employed for opening and closing the dc loop of the printer. V207 and V208 are connected in parallel and obtain their plate supply from the dc printer loop. In this circuit it is necessary to operate the cathodes of V207 and V208 at ground potential because the negative side of the dc loop is at ground potential. R236 and R237 are suppressors to prevent parasitic oscillation of the paralleled tubes. The electronic relay is keyed, opened or closed, by the keying voltage from the flip-flop keyer that is applied to the grids of V207 and V208. Under the "mark" condition, the keying voltage is approximately 1V negative which allows the electronic relay tubes to conduct, closing the dc loop of the printer. Under the "space" condition, the keying voltage is approximately 38V negative. This completely blocks V207 and V208 producing an open circuit of the dc loop.

(c) Monitor Sub-unit (SU301)

The monitor is a conventional oscilloscope circuit using one triode of a 12AX7, V301, as the vertical amplifier and employing a sinusoidal horizontal-sweep voltage obtained from the high voltage secondary of the power transformer. This circuit includes the usual oscilloscope controls, "vertical positioning", "horizontal positioning", "focus" and "intensity". The primary purpose of the monitor is for observing the tuning of the audio input to the discriminator and for determining the hertz shift that is being received. It displays the discriminator dc output. The audio input to the discriminator from the receiver is properly set by tuning the receiver until the pattern on the screen of the cathode ray tune, V302, is centred, indicating the frequency shift is symmetrical above and below the mean frequency. The hertz shift is determined by adjusting the vertical amplifier gain control, hertz shift, R301, until the pattern on V302 fills the space between the top and bottom parallel lines marked on the window in front of the tube. The hertz shift is then read directly from the calibrated markings on the control panel.

(d) Power Supply Sub-unit (SU401)

The power supply sub-unit furnishes all power required to operate the three sub-units contained in the frequency shift converter CV.89A/URA.8A, including filament, plate and bias voltages. A tapped primary is used on the power transformer for the selection of three line voltages, 105V, 115V and 125V.

(e) Cable Filter Assembly (Z505)

The cable filter assembly consists of four low-pass rf filters, tone input filter Z501, tone output filter Z502, teleprinter output filter Z503, and the ac input filter Z504. The purpose of this filter assembly is to filter out extraneous noise, or signals, that might cause the equipment to function improperly. Each filter is a low-pass type with cutoff frequency set for the frequencies in the particular circuit.

TERMINAL UNIT ADAPTOR FIELD CFS

General

Input frequencies: 445–470kHz.
Input voltage: 25mV from a 50Ω source at 465kHz.
Shift frequencies: 400–1,000Hz.
Output: 80–0–80V at up to 50mA for feeding two teleprinters.
DC feedback: A total drift of ±2·5kHz in receiver and transmitter ocillators is compensated by dc feedback. This facility may be switched-out if heavy adjacent channel interference is present.
Mark restoration: Mark restoration is arranged so that after a space signal, the keying circuits automatically return to the correct condition for the repetition of a mark signal.
Operational speed: 50 bauds (60wpm)

This terminal unit is designed to accept an i.f. signal from a receiver employing carrier frequency shift.

The equipment is mounted in two standard instrument cases with 19in panels, suitable for working one on top of the other or rack mounting. The adapter unit containing the frequency shift and telegraph circuits is contained on one panel, the power supply unit being contained on the other. All inter-connections are by *Plessey* Mk4 plugs and sockets.

Principle of operation referring to the block diagram, a simplified overall diagram of send and receive telegraph circuits is also shown. In this diagram the teleprinter terminal unit is the Army Mk4.

Frequency doubler V1: the output at intermediate frequency from the receiver is fed in through PL1 to a tuned circuit. Valve V1 has zero bias and conducts heavily. Its anode circuit is adjusted to twice the input frequency. Doubling is utilized to avoid difficulty due to instability, the output is RC coupled to V2 and V3.

These stages amplify the doubled output from V1. A variable negative voltage may be applied to the grid of V2 provided the "squelch" switch is on, this will prevent random printing between messages.

Discriminator V6 is a conventional Foster-Seeley, which converts the incoming frequency shift to a voltage change. The normal condition of working is such that a space signal produces a negative going voltage at the anode of V6 which via V10, V5, V7 and V12 cause the telegraph relay RLB1 to transmit a positive signal to line. Switch SWJ also permits the CCIT convention of a negative going space signal to be used by reversing the cathodes of V6.

DC amplier V10: this stage is a straightforward dc amplifier with a stabilized anode supply from V13 and V14 to prevent ht changes affecting the keying circuits.

Valve voltmeter circuit: V8 and V11 are both cathode followers enabling frequency drift to be measured when the meter switch is at "drift indicator". With signal input at the correct i.f. the grids of V8 and V11 are at equal and opposite potentials, therefore the meter connected between their cathodes will indicate zero. If the frequency drifts, however, the grids will have different voltages applied to them the potential difference across the cathodes will therefore cause a meter deflection proportional to drift.

Slicing circuits V5 and V7; valves V5 and V7 are cathode follower and cathode driven amplifiers respectively. These take a slice out of the centre of the waveform applied to the grid of V5 to enable noise voltages and distortion to be eliminated.

Keying circuit V12, V15 and V9B: V12 and V15 are space and mark keying valves respectively, each valve having one

winding of a polarized Carpenter relay in its anode circuit. Under quiescent conditions the grids of V12 and V15 and the cathode of V15 are at the same potential. When a signal is received it commences with a space, hence the anode of V7 goes positive. V12 conducts heavily, the current increase operating the "space winding" of the Carpenter relay. A resistor connected between the anode of V15 and earth ensures that the operating currents through the relay coils are the same on mark and space. The diode V9B ensures that the grid of V15 does not drift up in potential.

Receiver Adapter Controls, Plugs and Sockets

Dc feedback on/off switch: interrupts dc feedback line.
Squelch control RV1: adjusted to prevent random printing under low signal condition.
Meter switch: used with meter on panel, monitors teleprinter current frequency drift and voltages.
Systems switch: switches line circuits to either send, receive, or duplex.
Send current control: controls current from sending teleprinter.
Local printer monitors switch: connects local teleprinter to adapter output, sender input, or to input from remote sending teleprinter.
Local remote switch: enables a local or remote teleprinter to be used for sending.
Keying polarity switch: gives facility of receiving positive or negative going space signals.

Metering

The following facilities are provided by SW4 and meter M1.
Drift indicator: indicates frequency drift by reading out of balance voltage across the discriminator via valves V8 and V11.
Local receive: indicates receiving current when using local printer.
Send: indicates sending currents when using local printer.
Remote receive: indicates receive current when using a remote teleprinter.
Battery volts: indicates battery input voltage to power supply unit.

Telegraph circuits: an explanatory diagram showing the output circuit of the adapter, the teleprinter terminal unit and the teleprinter is given. The signal path for send and receive is shown by the thick lines. The system in use is assumed to be a two-wire simplex with local record and direct operation, **Fig 5.56**.

Power Supplies

The ac power unit is of conventional form, the transformer having tappings to permit 100/150V and 200/250V ac supply to be utilized. Full-wave rectification with voltage stabilizing is employed. A separate ac supply of 180V is taken out for use with the teleprinter rectifier MR1. This rectifier provides the voltage for the sender teleprinter supply.

Power supply voltages: set the supply unit voltage selector to the correct voltage. Switch on with the adapter connected and check that the voltages given below are present:

PL2	*ac operation*
PL2 J-H	315/336V dc
PL2 D-F	18/20V dc
PL2 E-K	6/6·6V ac
PL5 J-H	90/110V dc
PL5 G-H	90/110V dc

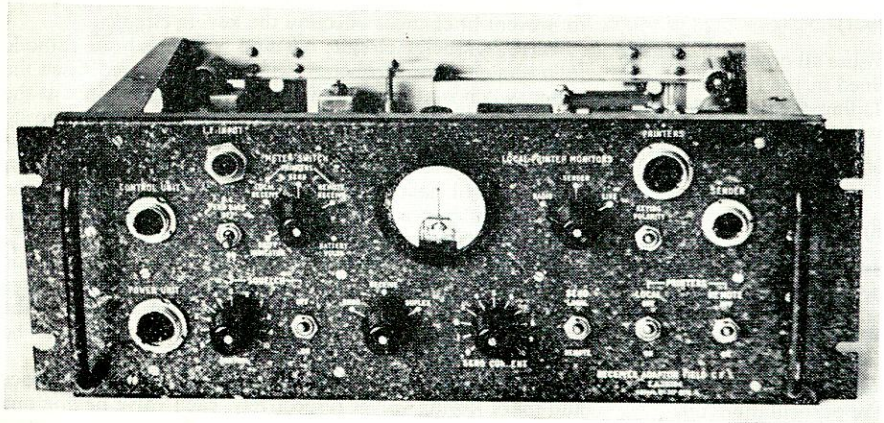
Setting-up Procedure

Looking in the top of the unit, at the front right-hand side are mounted three potentiometers, numbered from the left RV5, RV3 and RV2. These should be adjusted as follows:

RV2 should be adjusted for 125V between wiper, tag and chassis. A test meter should then be connected between V10 anode and chassis, and with the dc feedback switch turned to "on", RV3 should be adjusted until the test meter reads 35V. With the dc feedback switch turned to "off", RV5 should be adjusted until the test meter reads 35V. Disconnect test meter.

Establish the i.f. frequency of the receiver to be used to drive the CFS adapter and feed into the input socket of the adapter a signal at the centre i.f. frequency. The transformers at the left-hand side of the chassis should now be adjusted for maximum voltage as read with a valve voltmeter at V3 grid.

The discriminator tuning should now be adjusted for a centre meter reading of meter M1, with the dc feedback switch at "on", when the lower core of L4/L5 is adjusted. It should be possible to obtain an even swing about zero when this core is turned. Finally the top core of L4/L5 should be peaked for maximum voltage as measured with a valve voltmeter at V3 anode.



Receiver Adaptor Field CFS.

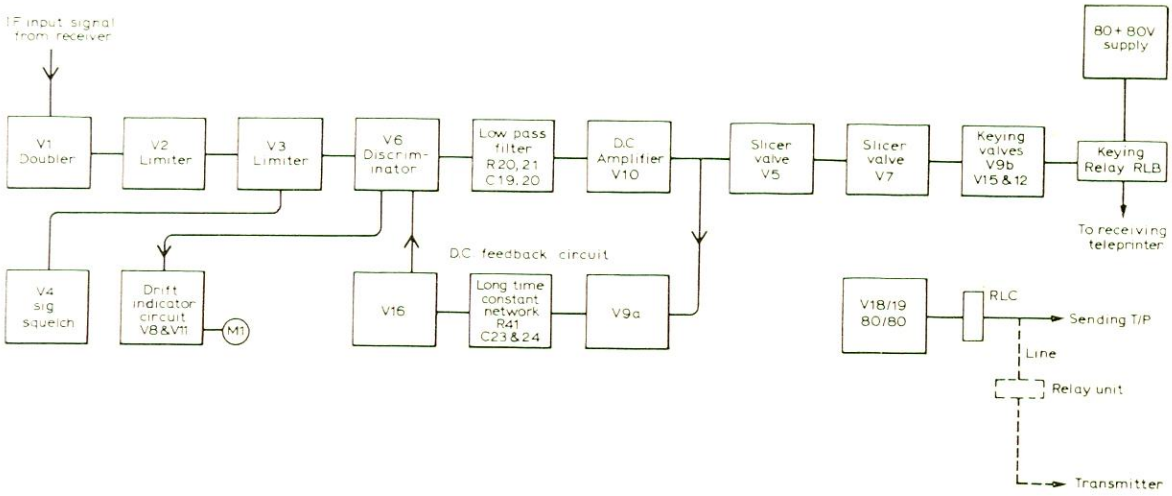
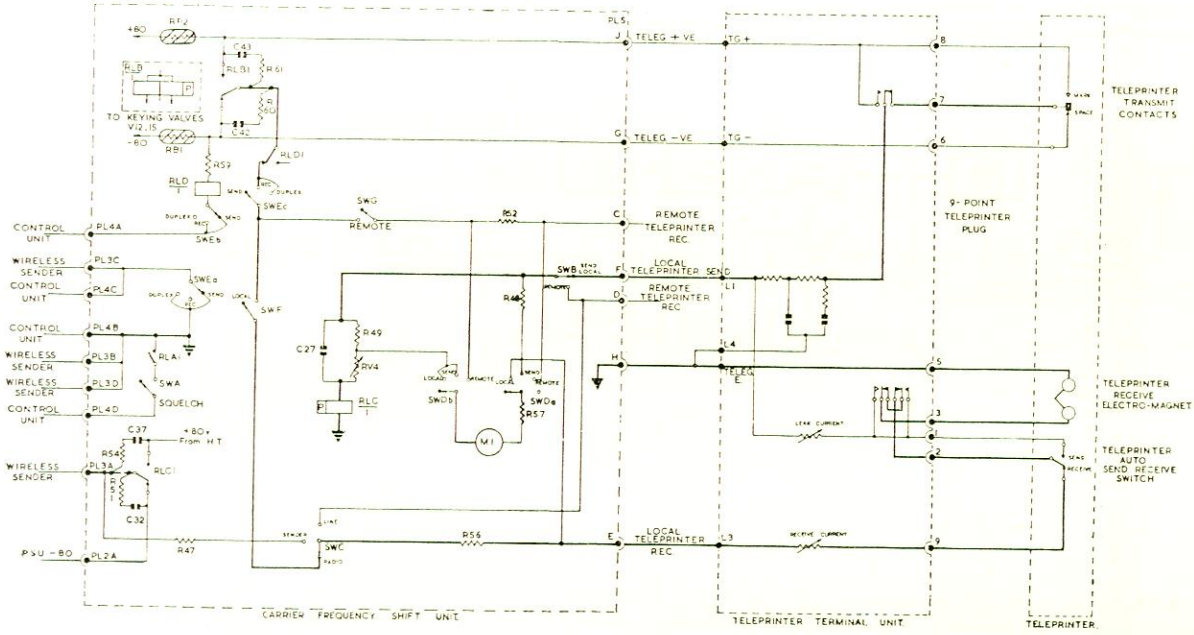


Fig 5.55. Block diagram of adapter, field, CFS.

Fig 5.56. CFS, simplified telegraph circuit.



DUAL-DIVERSITY RECEPTION

How utilization of space and polarization diversity technique can greatly reduce printing errors in radio-teleprinter reception

Nowadays there are many fine rtty converters in use which are able to copy a signal by mark-only or space-only signals during conditions of frequency selective fading. This type of frequency-diversity converter out-performs the older types where both mark and space tones together were necessary for satisfactory printing. Despite this improvement, there will be moments when the signals fade out completely, therefore another approach is called for, and the purpose here is to outline practical methods to those interested in improving their copy. If two receivers are available that are connected to independent aerials, it is possible to realize a substantial improvement by combining the outputs of each receiver path and passing this combined signal on to the converter. If, as in most cases, only a single receiver is on hand, a simple system of electronic switching called "aerial-switch diversity" may be used. The advantages and disadvantages of both of these forms of diversity operation are presented with practical methods outlined.

Using Two Receivers

A flexible system is herein outlined of a practical dual-receiver method whereby frequency and space diversity technique is utilized to full advantage.[1] Polarization diversity may be used in place of space diversity, as will be explained later. Looking at **Fig 5.57**, and assuming both receivers are of the same type, only one high-frequency oscillator is used. This ensures that both intermediate frequency outputs will be identical in frequency. For example, the hf oscillator in the A-path receiver will be used in the normal way, but in addition it will be fed to the B-path receiver mixer. The hf oscillator in the B-path receiver is purposely disabled. Both receivers are switched to the a.m. position with AVC on. The mark BFO and space BFO inputs are mixed with the i.f. signals input of all frequency changers from which individual mark and space tones are obtained. These tones are passed on to the mark and space amplifiers where they undergo bandpass filtering. In this demodulator all four tones are adjusted to the same frequency. Consider a typical case where it is required to copy an rtty station sending with an 850 cycle shift. The two receivers may have i.f. outputs of 455kHz. The table in **Fig 5.58** shows the mark BFO will be set 3kHz higher than the received mark i.f. signal, and the space BFO will be set 3kHz lower than the received space i.f. signal resulting in 3,000 cycle tones throughout. The advantage of this circuit arrangement is that a selection of any tone frequency may be made to match the bandpass filters selected, and since all mark and space tones are identical, the gain-slope loss profiles of the bandpass filter circuits will be alike. This fact will aid in minimizing signal bias distortion. When copying different shifts, it is unnecessary to change mark and space tone filters. For example, when copying a 200 cycle shift, it is only necessary to reset the mark and space BFO adjustments until the tones fall into the range of the filter passbands, as shown in **Fig 5.58b**. In this system limiting has not been used up to the point where final combining takes place. All mark and space channel amplifiers use delayed automatic gain control (AGC) which is taken from their outputs after rectification, and may be fed back to the common AVC lines in both receivers if desired.[2] Each tone channel amplifier has its input circuit connected to this AGC line as well, to prevent overloading from very strong signals.

Detection and Common Load Combining

After tone filtering and amplification take place, the two mark tones go to separate full-wave diode detectors having parallel output connections. From this point, the stronger of the two rectified mark signals passes through a low-pass filter so that any audio signal residue is reduced to very small

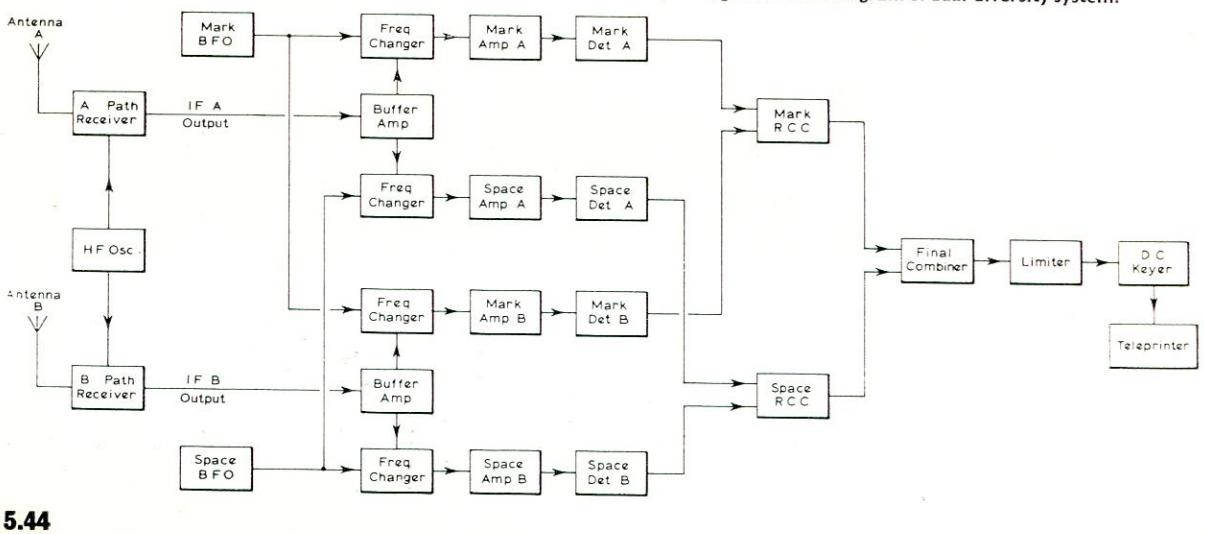


Fig 5.57. Block diagram of dual-diversity system.

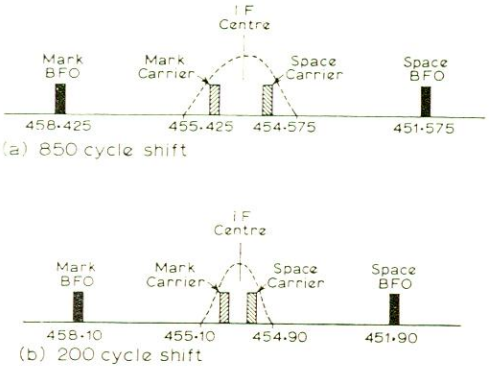


Fig 5.58. See text.

transition. The RCC stages therefore remove bias in the process and also follow the fading pattern of the mark pulses and of the space pulses independently from each other. Both RCC outputs are fed to a mark-to-space combining circuit which will operate satisfactorily when either the mark or space signals exist singly or both together. Copy from a single tone will be satisfactory providing the signal-to-noise ratio equals or exceeds 6dB. After the mark and space pulses have been ratio-corrected, they operate an emitter-coupled combiner where the output connects to a normal-reverse sense switch, and then on to the decision and limiting circuit. Finally, a dc keyer stage is used to operate the teleprinter magnet circuit.

Circuit Particulars

One of the principal objectives in this demodulator is low intermodulation distortion of all tones in order that signal

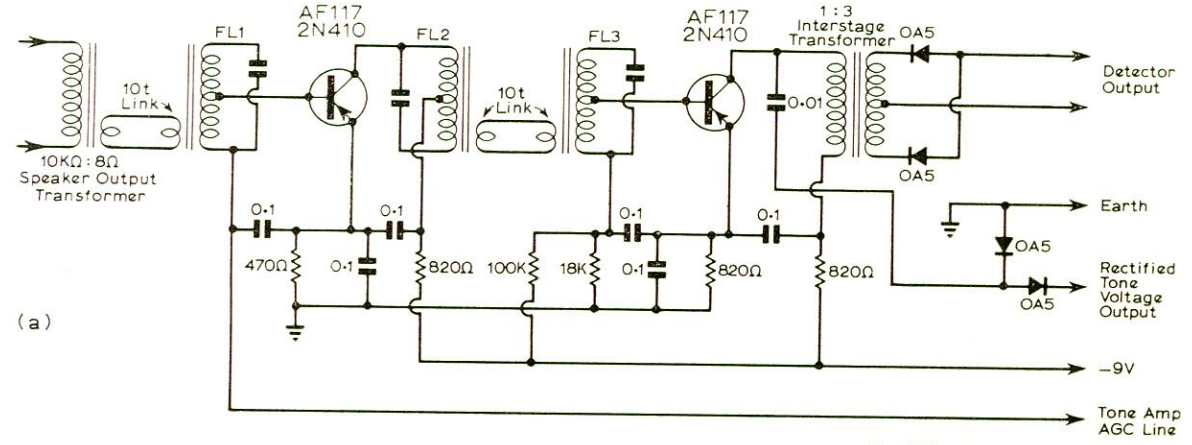
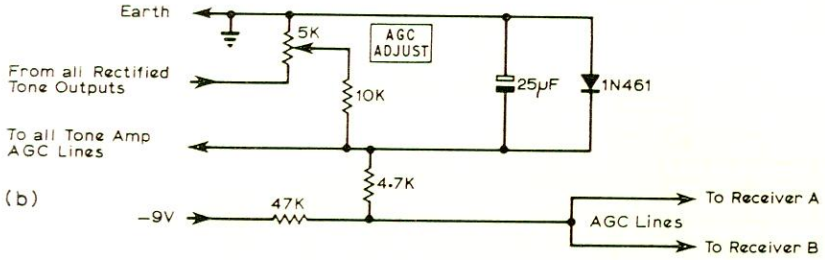


Fig 5.59a. Circuit diagram of tone amplifier with full-wave detector.



LEFT:
Fig 5.59b. Common AGC network for combining four-tone amplifiers.

levels. Choke L and resistor R make up the common load combiner circuit for the dc intelligence pulses which may contain bias distortion. Detection and common load combining of the space tones takes place in exactly the same way as for the mark tones just described.

Ratio Correction Circuit

Two ratio correction circuits (RCC) take the separated mark and space pulses which may have unequal amplitudes and, without limiting, adjust the ratio between the positive and negative potentials at each signal transition so that the mark-to-space decision is made at the mid-point of the bias can be kept to a minimum. The four frequency changers can be product detectors to help achieve this end. **Fig 5.59a** is the schematic of one of the four tone channel amplifiers with full wave detectors. Both detector outputs of the mark tone channels are paralleled and are connected to the input of the common load mark combiner. The same is true concerning the two space tone channels and common load space combiner. Bandpass filters FL1, FL2 and FL3 consist of three toroidal centre-tapped coils with coupling links of perhaps 10 turns, but the builder may wish to try alternate arrangements. The four tone channel amplifiers also are directly coupled to a common AGC network, **Fig 5.59b**, and a delayed AGC bias is produced and passed back to the

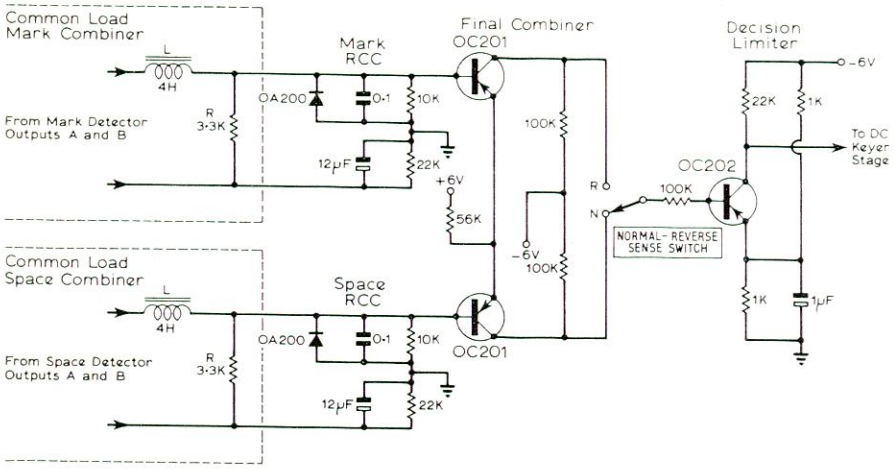


Fig 5.60. Circuit diagram of common load combiners, ratio correction circuits and decision limiting circuit.

AGC lines of both receivers. The common load combiners, ratio correction and decision limiting circuits are detailed in **Fig 5.60.** An equivalent valve RCC circuit is given in **Fig 5.61** with its waveforms presented in **Fig 5.62.** It will be seen from **Fig 5.62** that the complete intelligence is obtained from either of the tones by itself and it is not necessary to have both tones present in order to get bias-free signals. The R1C1 time constant follows the telegraphic keying rate and the R2C2 time constant follows the fading envelope of the signal. Another important advantage to these RCC circuits is that it is not possible for them to remain locked in the wrong condition while either mark or space pulses are being fed to their inputs. Valves could also be used throughout such as an fsk diversity demodulator with equally fine results.

Aerial-switch Diversity with One Receiver

Outlined is a simple system whereby two separate aerials are electronically switched through a pair of rf diode changeover gates whose outputs are joined together and fed to the rf input of a single receiver. Any conventional two-tone or i.f. type converter can be used for effective results. A free-running multivibrator at ultrasonic frequency is used to drive a control circuit which rapidly switches the current-driven silicon diodes.[3, 4] There is no need to mention the obvious economic advantage of this arrangement outlined in **Fig 5.63.** Important features of this rf selection switch are low insertion loss, high attenuation between input and output when in the off state and a virtual absence of switching transients. Excellent isolation with low insertion losses can be readily obtained in practice. Another diode gate circuit[5] exhibited isolation figures of 85dB at 20MHz and over 70dB at 30MHz with less than 4dB insertion loss.

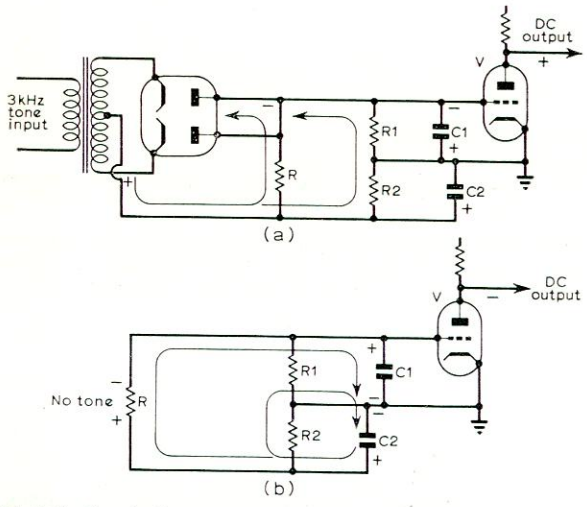


Fig 5.61. Circuit diagram of basic value ratio correction circuit, showing current flow (a) tone input and (b) no tone input.

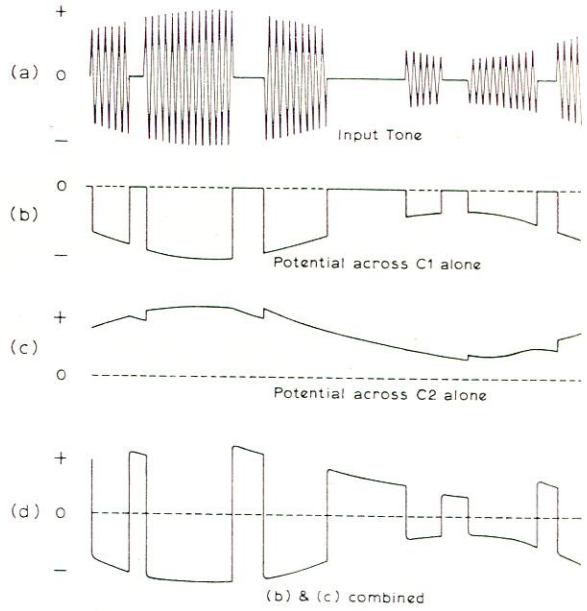


Fig 5.62. Voltage waveforms associated with Fig 5.61.

Diversity-aerial Layout

Comprehensive investigations of diversity receiving aerial arrangements have been made to determine the effectiveness in reducing signal interruptions due to deep fading.[6] In the case of space diversity, much data was collected for two horizontal half-wave doublet aerials installed at a height of about 45ft in the frequency range of 7–16MHz over a 900-mile path. Aerial spacing of 100ft gave a value of 0·2 per cent non-usable time. When 200ft spacing was tried, the non-usable time dropped to 0·08 per cent. Finally, a spacing of 1,000ft was tried and the non-usable time dropped to 0·05 per cent. Conclusions are that spacings greater than 100 or 200ft are not necessary since there is relatively little improvement in performance. It is quickly realized that most people will not have enough land to install aerials with a separation of 100–200ft. There is only one answer for small confined areas and that is to use aerial polarization diversity. One practical way is to use a horizontal dipole approximately 50ft above the ground and a vertical half-wave dipole suspended by an insulator at one end of the horizontal element in an inverted-L arrangement. Another method is to use a single pole in an inverted-V arrangement that is easy to erect. Two aerials are suspended from the top of the pole to opposite points on the ground at angles of 45 degrees to the horizontal plane. The angle between aerials is thus 90 degrees. Alternate polarized aerial configurations can be in the form of a T, or if two poles are available, an X arrangement might be used. The separation at the centres where the aerials cross

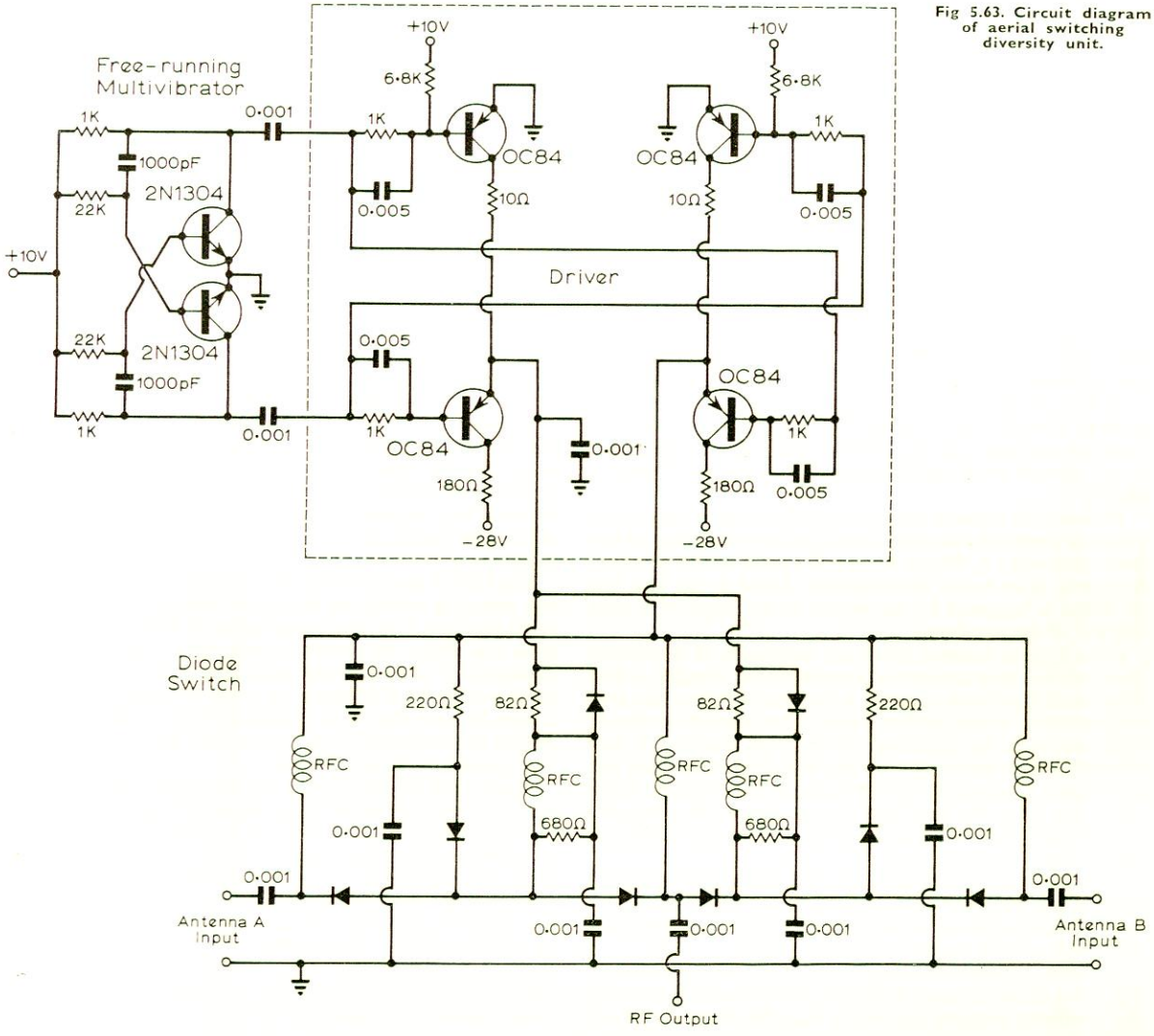


Fig 5.63. Circuit diagram of aerial switching diversity unit.

may be about 1ft. Regardless of which aerial configurations are used, both lead-ins should be brought out from their aerial centres at right angles for distances of 50ft or more so that possible interference effects from coaxial cable lead-ins will be minimized.

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ELECTRONIC REGENERATIVE REPEATER TYPE TRR–2 (Fig 5.65 inset)

The repeater is designed to accept rtty signals which have distortion of up to 49 per cent on either "mark" or "space" and to regenerate them so that they contain no less than 1 per cent distortion. Provision is made for varying the stop element from 1·3 to 1·7 units for automatic stop element insertion and one unit for constant stop element insertion. It will operate at all standard speeds, ie 45·5, 50, 57 and 75 bauds.

Basically the repeater restores each character to the correct length of significant elements once a genuine start element has been received by it. Within the unit is a pulse oscillator whose frequency is set to suit the teleprinter speed in use and this oscillator is triggered by the arrival at the input of a start element of the rtty signal.

Once a signal element, albeit not necessarily of the correct duration, has been accepted as genuine by the repeater, a start element of the correct duration is sent to the output line and, similarly after a time interval equal to the selected number of elements from the beginning of the start element, a stop element is then sent to line by the repeater. Even when the stop signal is missing in the input signal, the oscillator is cut off at the right time and held for the natural duration of a stop element or until the arrival of a genuine one, whichever comes first.

The speed of the pulse oscillator can be checked by using a fork as the frequency is displayed on the front panel by a neon. A control gives a variation of ±6 per cent on the centre frequency of each range.

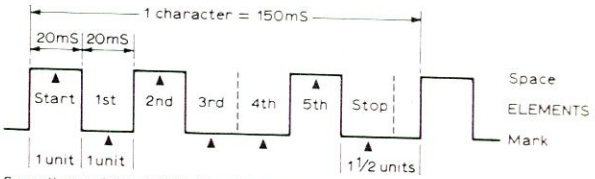
A switch is provided which in the "out" position connects the input of the repeater directly to the output while leaving the oscillator running so that it may be checked without disturbing the channel. In the event of ht failure, a relay is built in which again bypasses the repeater and allows the signal to be passed to line with the repeater out of circuit.

Both input to and output from the repeater is by a polar relay at each end; this enables the unit to accept either double or single current signals.

Circuit Description

In **Fig 5.64** it can be seen that the letter "F" as sent in start stop telegraph signalling consists of a number of equal-length elements with a nominal length of 20ms. There are seven of these elements in all; one for start and stop and five representing the character to be sent. In the case shown of 7½-unit code the final stop element is 1½ times the length of the other elements.

When this form of signal is used in a circuit such as radio where it may be subject to distortion by spurious signals, missing elements and fading, the time at which the change-



Sampling points at 50% Margin are indicated by arrow-heads

Fig 5.64. Character element of letter F, 7½-unit code, 1½-unit stop element.

over occurs for a particular element may be displaced causing the changeover to happen earlier or later than would be the case in the original signal. The receiving printer is started by the first start element and then depends upon the arrival at the correct time of the other elements for the correct reproduction of the character. It does this by sampling the centre of each element in turn relative to the time of arrival of the start signal, ie at 30, 50, 70, 90 and 110ms from the beginning of the start signal.

The TRR-2 does a similar function but the point at which this sampling occurs can be varied from 20 per cent before to 20 per cent after the centre point of each element. This gives the ability to obtain correct copy with changeovers displaced by up to ±49 per cent. This ratio can be adjusted in favour of mark-to-space or space-to-mark changeovers. It can be seen that with sampling at the centre point the output of the repeater is delayed by half an element or 10ms with respect to the input signal.

When used for purposes of rtty reception there may occur short duration pulses of space signal which may last but a few milliseconds and may arise as a result of noise, fading or interference from an unwanted signal on an adjacent channel. If this happens during one of the code elements that determine the character then an incorrect character will result. Using the repeater, however, this can only happen at the instant of signal sampling. Furthermore, if it were to occur at the interval between characters, the repeater might see it as a start element and so trigger the oscillator resulting a loss of synchronism were a genuine character to come along during

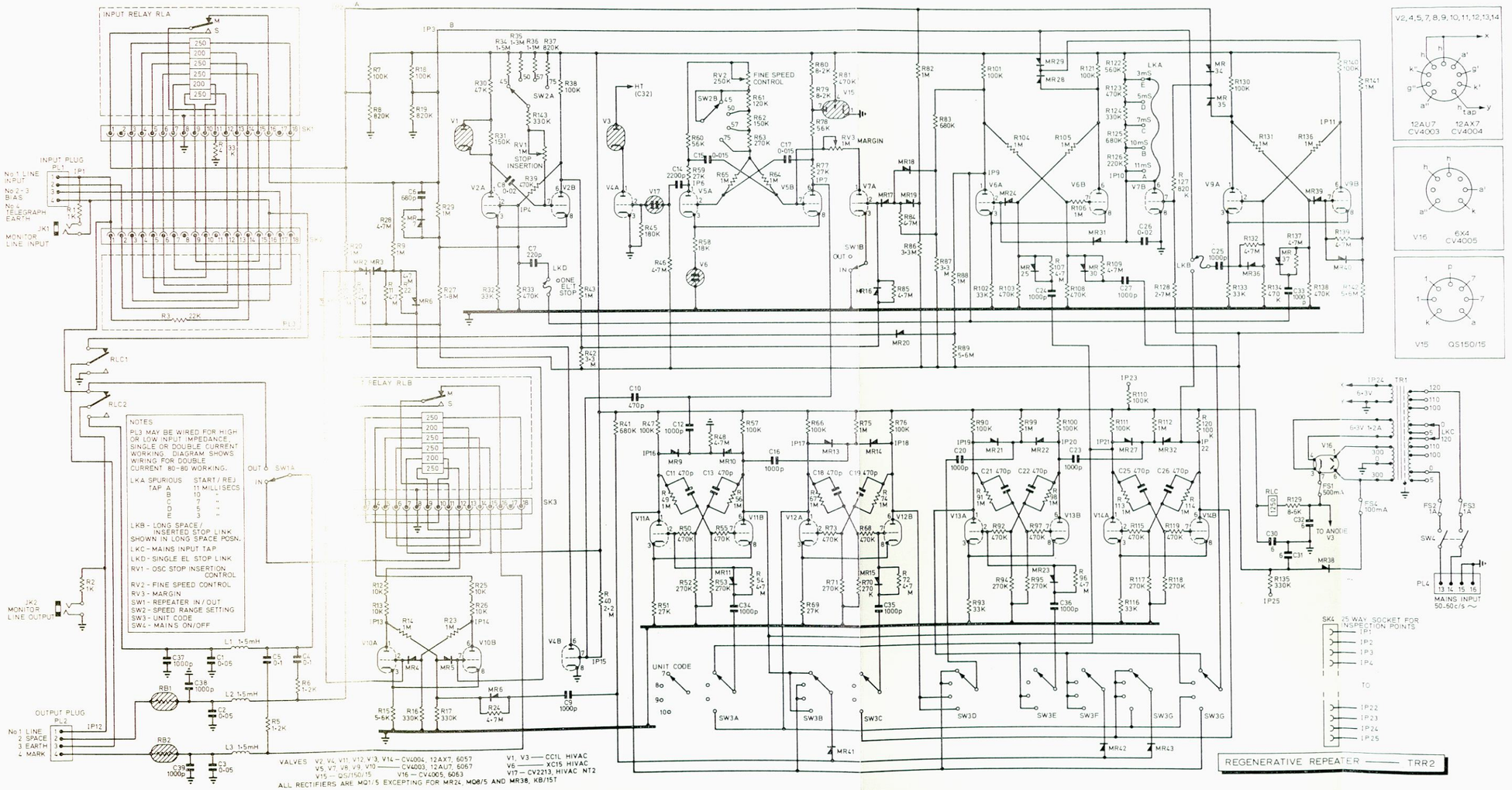


Fig 5.65. Circuit diagram of TRR2 regenerative repeater.

the course of the oscillator's output. This eventuality is taken care of by the incorporation in the repeater of a circuit which is timed to reject all space signals of duration less than a predetermined time. A preset arrangement allows rejection of start elements less than 3, 5, 7, 10 or 11ms. Thus, once a start element has been accepted by the repeater as genuine, an element of the correct duration is sent to the output and the full character cycle is started. In exceptionally bad conditions it may be that whole elements are lost and if this happens to be one of the code elements, an incorrect character will result. If however the final stop element is lost the oscillator would simply start a further character cycle as the input would detect a start signal resulting once more in a loss of synchronization.

To prevent this happening and to make sure that a stop element of the correct duration is fed to the output, another circuit is included which inhibits the oscillator after it has generated the required number of pulses for the code in use. The time during which the oscillator is held off is controlled by a potentiometer to give a stop element duration of 1·3 to 1·7 units as needed. At the end of this period or after completing a genuine stop element the repeater is in readiness for the following character. The repeater has a neon indicator on the front panel so that dropped elements can be observed.

Operational Details

The repeater is designed to be mounted on a standard 19in rack with four screws. The front panel is 19in × 3 $\frac{15}{32}$in.

width 17 $\frac{3}{16}$in
depth 10$\frac{3}{4}$in
weight 23lb.

Mains input is by way of a four-pin connector and can be altered to suit ac mains between 100–240V.

Input and output connectors are smaller four-pin types.

The ht relay is plugged into the rear panel.

Both signal relays are on the front panel.

Variable single stop element adjustment is located on the bottom group board which folds out of the unit when the cover is removed.

Spurious start rejection adjustment is at the rear inside a removable socket.

Automatic stop insertion—long space. Accessible near the input relay socket after removal of the cover.

To put the repeater into service it must first be mounted in a standard 19in rack.

Check the supply voltage and connect input and output connectors. Connect to the power source and with the "in/out" switch set to "out", switch on power. Allow about 10min for the unit to warm up before checking the speed. This is done with the aid of a stroboscope tuning fork as follows.

Remove the front protective cover to expose the speed neon V3. Check that this is glowing and then observe the neon through the fork shutters. When the speed is almost correct the neon will be seen slowly to light and extinguish. Final adjustment is made by rotation of RV2 accessible at the right-hand side of the unit after the cover has been removed. Correct speed is when the neon appears to remain alight or extinguished. The oscillator frequency now coincides with that of the fork. Replace both covers. The unit is now ready for operation at the speed to which it has been set and when the operational switch is thrown to "in", the signal fed to the input relay causes the repeater to process it and feed the processed signal to the output via the second high speed relay.

Maintenance

Apart from voltage, relay and valve checks, maintenance of the TRR-2 requires the use of a good TDMS such as the A.T.&E. 6 EB or a combination of the 6EB and 5EB. This test equipment is essential because of the necessity for the accurate measurement of the various characteristics of the signal fed to the unit under test. The high speed relays can very easily be set for neutrality and the contact bounce measured with the 5EB or 5B TDMS. Transit time can be measured at the same time.

Valve voltage checks are facilitated by a test panel on the front of the repeater. These are listed in the table.

In addition to the TDMS a good double beam oscilloscope is required fully to cover all the tests on the repeater. Many of the waveforms can be obtained from the test panel on the front mentioned above.

For 50 baud speed a stroboscope fork of 100Hz should be used.

The complete test procedure for the TRR-2 is complex and special test equipment as stated above is required. It is strongly recommended that attempts to carry this out without both the equipment and the full test manual will be more likely to degrade the performance of the unit than to enhance it.

The usefulness of the repeater was particularly apparent with some of the earlier types of terminal unit in use for rtty. With more recent designs, however, the benefits are more obscure but many users have found that, properly set up, the TRR-2 can produce worthwhile improvement in the received copy.

A SIMPLE REGENERATIVE REPEATER

This describes the principles of operation and the circuitry of a simple regenerative repeater, that is, a device that will accept a 7½-unit rtty signal that has suffered some distortion, and repeat this at the output of the unit, but without the distortion. In commercial systems, a number of repeaters can be connected at points along a long line of relay stations to "clean up" the signal, so that the distortion does not accumulate, as it would do if the repeaters were not present. Examples of these repeaters which have appeared on the surplus market from time to time can also find use in the amateur shack, connected between the terminal unit and the printer. An improvement in the copy results, since the repeater will operate successfully with a more distorted input signal than a printer could handle on its own without making errors. If the printer is old and out of adjustment, the improvement in copy is even more marked.

The circuit, **Fig 5.66**, contains two bistables, a delay line timing generator, and a number of other transistors, 15 in all. The first bistable, which will be known as the character bistable, and the timing generator, will be desrcibed first.

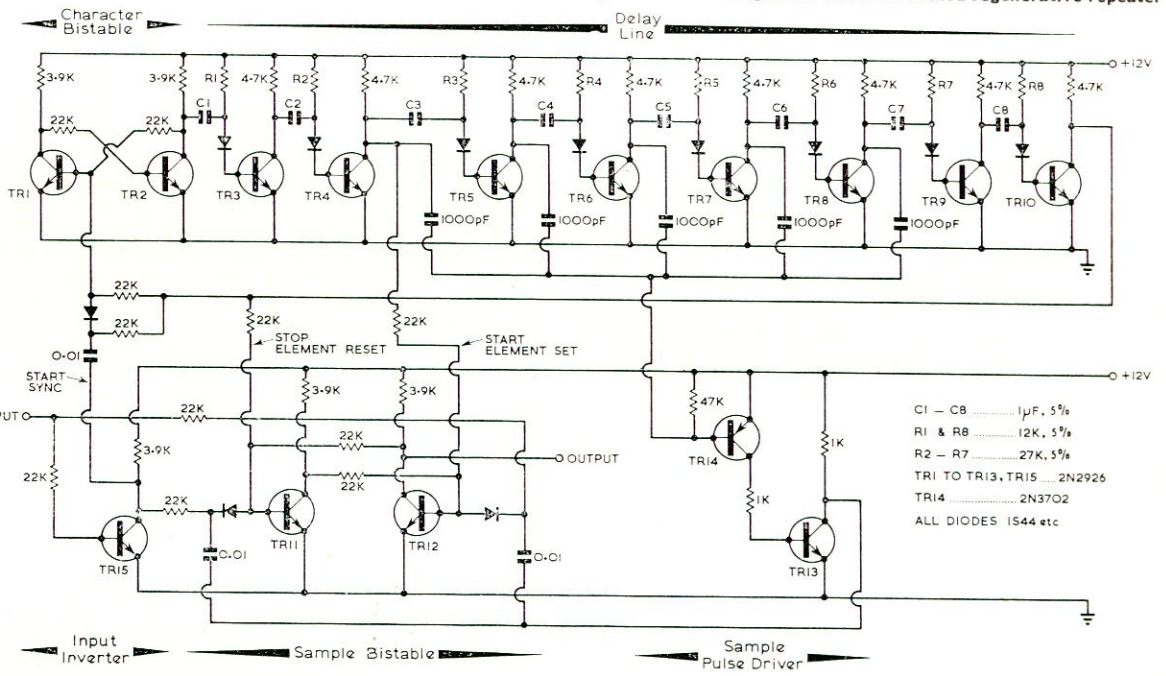
Before a character is received, the input is at zero volts (mark), and TR2, of the character bistable TR1/TR2, is off. All the transistors in the delay circuit TR4-10 are on. When the input signal goes to 12V (space) at the beginning of the start element, TR15 switches on, its collector dropping to

zero. A negative pulse is fed through the 0·01μF capacitor and the steering diode, to the base of TR1, switching it off. So the character bistable changes state, and TR2 collector drops to zero. C1 was charged to 12V, so now it drives the base of TR3 negative, switching TR3 off for a period of time dependent on the time constant C1R1. During this time C2 has charged up to 12V since TR3 is cut off. At the end of this time, TR3 comes back on again, and so C2 takes the base of TR4 negative, cutting off TR4, for a time determined by the time constant C2R2. This sequence occurs all the way down the line TR3-10, each transistor being cut off in turn for an accurately known period of time. **Fig 5.67** shows the waveforms at each of the transistor collectors in the timing generator, showing the exact times involved, starting from the instant of the incoming start element. The negative going edges of the signals at the collectors of TR4-8 are coupled through 1,000pF capacitors to TR14, switching it on for five brief instants. This switches on TR13. Thus a row of five negative going pulses is formed at the collector of TR13, also shown in **Fig 5.67**. The timing is arranged so that these five pulses occur at the exact centres of the expected input signal's code elements. These pulses tell the repeater when to "look" to see whether the input is a mark or a space.

The "looking" operation takes place in the other bistable, called the sample bistable, and which comprises TR11, TR12, and two steering diodes. The input signal to the repeater is fed to one steering diode, and also, after inverting by TR15, to the other steering diode. If the input is a mark (zero volts) when a sample pulse occurs, then TR12 will receive a negative pulse on its base from the sample pulse driver TR13 via the 0·01μF capcitor. TR11 will not receive a pulse, since its steering diode is reverse biased by 12V from TR15 collector. The negative pulse on the base of TR12 will turn it off (if it was not already off), and the bistable will stay in this state until the next sample pulse. If by then the input has changed to a space (12V), then the sample pulse will be steered to switch off TR11. Thus the signal at the collector of TR12 is the same as the input signal, but "cleaned up", and also delayed by half an element, or 10ms.

The signal at the collector of TR12 is to be the output of the unit, but first it must be provided with the start and stop signals at the correct times. Since the code elements of the output signal are delayed by 10ms, the start and stop signals must also be delayed. From the collector of TR4, the second transistor in the delay line, a resistor is connected to the base of TR12 in the sample bistable, so that during the time that TR4 is off, TR12 is on, thus holding the output to 12V (space) irrespective of the input signal. The timing has been arranged so that this starts 10ms after the start element of the input signal, and so is at the correct time for the start element of the output signal. The stop element is produced in the same way, by connecting a resistor from the collector of TR10, the last in the delay line, to the base of TR11. This returns TR12 to zero at the correct time for the beginning of the stop element, again, irrespective of the input signal. The signal at TR10 collector is 10ms long, and no longer, to allow the next character to start earlier if there is some distortion on it (or indeed if the start element of the current character occurred late). If this signal was longer, there would be no room for speed or jitter errors between characters. A resistor from TR10 collector to the base of TR1 resets the character bistable, and a further resistor to the steering diode on TR1 base holds the trigger circuit out of action until 10ms before the next start element is expected. This also allows time for C1 to charge up to 12V again, ready for the next character. The operation is now complete, and the

Fig 5.66. Circuit diagram of a transistorized regenerative repeater



repeater will now wait until the next character, which, on automatic transmission, will come about 150ms after the last one, and on manual transmission, could come any time after 150ms, depending on the operator's typing ability.

The only components which are critical in this circuit are the timing components C1-8 and R1-8, which should be 5 per cent tolerance. If an oscilloscope is available for alignment of the repeater, cheaper components can be used, and the individual time constants trimmed to the correct values by paralleling small capacitors or large resistors across the appropriate components. The components shown give the correct values for 50 bauds. The RC product in each case should be increased by a factor of 11/10 in each case for 45 baud operation, or extra resistors switched in for dual speed operation.

No mention has been made of the connections from the tu and to the printer, as this will depend on the local loop arrangements at any particular station, but as an example, for a 80–0–80V loop system, a polar relay can be driven from the line that would normally drive the printer magnet, with a contact pair connected between the 12V line in the repeater and the input point; on the output of the repeater, a power transistor driven from the output terminal can be used to operate a high speed relay with a change-over pair of contacts to drive the printer magnet from the 80–0–80V loop supplies.

Setting Up

As mentioned earlier, an oscilloscope is very useful for lining up the repeater, although it should work first time if the timing components are right, and there are no wiring faults. If an oscilloscope is available, then it can be used to check all the waveforms in **Fig 5.67**, while the unit is working from, say, a tape reader which is running a continuous RY tape loop. Synchronize the oscilloscope from the input signal with an external triggering lead, making sure that the start element of each character is at the left hand end of the trace, so that the waveforms can be checked against each other, and with **Fig 5.67.**

If the timing components need to be trimmed, a calibrated timebase is an advantage, but if this is not possible, then the signal from the tape reader can be used to set the timebase speed to line up with the oscilloscope graticule lines, and the time constants aligned accordingly. It should be remembered that adjustment of the earlier time constants will affect the position of the later ones, so the early adjustments should be performed first.

If an oscilloscope is not available, the unit may be roughly set up with the aid of a printer. First disconnect the 0·01μF capacitor from the collector of TR15, and hook it on to the collector of TR10. This will have the effect of causing the delay line to recycle continuously, once started off. Temporarily change the value of R8 to 27kΩ. This makes the stop element of the recycling output signal the correct length. With the unit switched on and the output connected to a printer, momentarily short the collector of TR2 to earth. This triggers the character bistable, and the repeater will now recycle continuously, and the printer will print "ltrs" and at the correct speed. Connect the input terminal to 12V, and the printer will now print blanks (of course, neither of these characters actually prints anything). A final, novel, check is to connect the input to the collector of TR11, when the printer will print the letter "Y" continuously.

By switching the repeater in and out on successive repeats of the test message, and counting errors over a period of an hour or so, improvements of up to seven times have been noted in the error rate. In general, the better the copy to start with, the better the improvement on inserting the repeater. Since the repeater synchronizes to the incoming signal in the same way as the printer does, namely from the leading edge of the start element, errors here will not be improved by the repeater. However, on average, only 1 in 7½ errors will affect the start element, so little is lost. On automatic transmission, bursts of errors sometimes occur

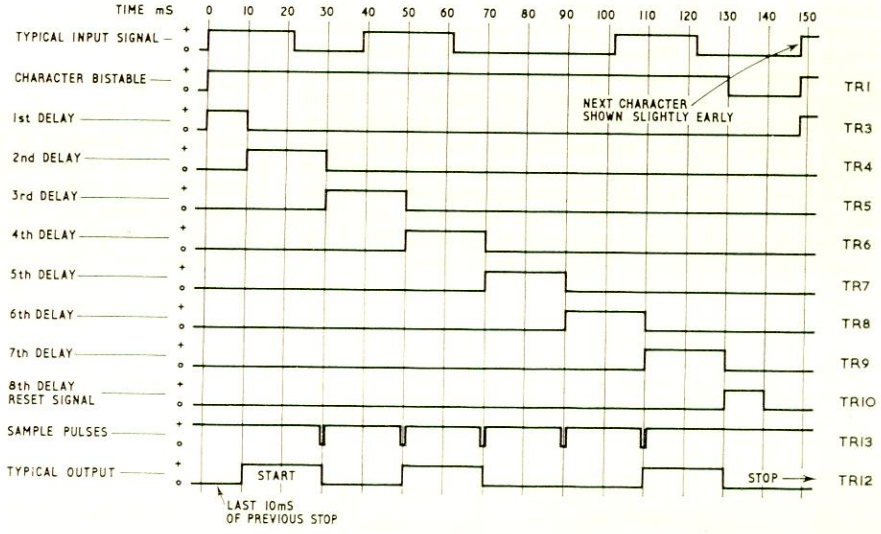


Fig 5.67. Timing diagram of the transistorized regenerative repeater.

due to loss of synchronization, while the printer selector mechanism falsely takes space elements as start elements. It may take up to five characters to get in step again. The repeater will, on average, take only half this time, and so less characters will be missed.

Possible refinements could include dual speed switching, facilities for switching the repeater in and out of circuit at will, and a variable time constant of 5–15ms in place of R1C1, thus providing the electronic equivalent of the "orientation" control on some printers.

THE PHASE-LOCKED LOOP

The integration of tuned circuits has long been hampered by the absence of a good substitute of inductances. Many schemes have been developed, but most suffer from a variety of problems, an important one being frequency stability.

In a new series of integrated circuits developed at *Signetics*, these problems have been overcome. By integration of the Phase Locked Loop, *Signetics* has developed a precisely tuned integrated circuit without the use of precision components.

The Phase Locked Loop (PLL) is by no means a new idea. It has been used for years to track satellites, stabilize the frequency of klystrons, and filter information out of noise. In discerete (non-integrated) form, however, the PLL is generally too complex or expensive for many less rigorous applications such as fm demodulation or frequency multiplication. In integrated form, however, the cost of even a complex circuit is small, so that the PLL offers new solutions in applications where it might not otherwise have been considered.

Fundamentals of the Phase Locked Loop

The PLL, shown in **Fig 5.68**, consists of four basic building blocks; the phase comparator, the low-pass filter, the amplifier and a voltage controlled oscillator (or VCO). At the heart of the loop is the phase comparator. The phase comparator is essentially a multiplier, which mixes the input signal with the VCO signal to produce the sum and difference frequencies, $f_s + f_o$. When the loop is in lock, however, the VCO duplicates the input frequency so that the difference frequency ($f_s - f_o$) is zero, and hence the output of the phase comparator contains a dc component. The phase comparator output is then filtered to remove the sum frequency component $f_s + f_o$, and the remaining dc component is amplified and fed back to the VCO. It is this error voltage which drives the VCO to keep $f_s = f_o$ when the loop is in lock. The magnitude of this error voltage is a direct function of the phase relation between the VCO and input signals.

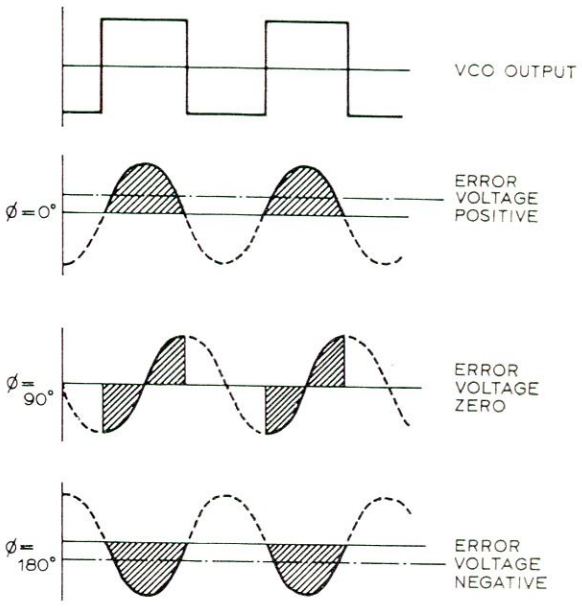


Fig 5.69. See text.

Fig 5.69 shows how the error voltage is affected by the phase difference between the two signals. The VCO signal is a square wave in this case. When the loop is out of lock, and the difference between f_s and f_o is large, both sum and difference frequencies are filtered by the low-pass filter and the VCO runs at its present frequency. As the difference between f_s and f_o approaches the cut-off frequency of the low-pass filter, however, a beat note forms which tends to force the VCO frequency, f_o, towards the input frequency, f_s. When the dc component of the beat note becomes large enough, the VCO frequency reaches the input frequency and the loop achieves lock. Consequently, the loop selectivity is a function of the low-pass filter. Once in lock, the loop will track signals over its entire lock range.

Circuit Design

In a Phase Locked Loop, the distortion is primarily a function of the linearity of the VCO. To achieve the highest possible linearity, highly predictable and accurate integrated constant current sources were used to charge and discharge an external capacitor. The high degree of linearity arises from the accurate current-to-control-voltage characteristic of the integrated current sources.

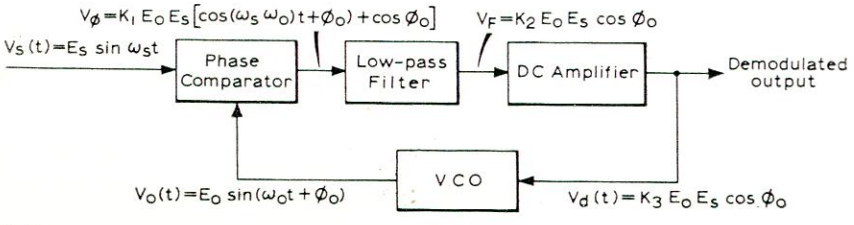

$V_\phi = K_1 E_o E_s [\cos(\omega_s \omega_o)t + \phi_o) + \cos\phi_o]$
$V_F = K_2 E_o E_s \cos\phi_o$
$V_s(t) = E_s \sin\omega_s t$
Phase Comparator
Low-pass Filter
DC Amplifier
Demodulated output
VCO
$V_o(t) = E_o \sin(\omega_o t + \phi_o)$
$V_d(t) = K_3 E_o E_s \cos\phi_o$

Fig 5.68. Block diagram of a phase locked loop.

A simplified diagram of the VCO is shown in **Fig 5.70**. I_1 is the charging current created by the application of the control voltage V_C. In the initial state, T_3 is off and the current I_1 charges the capacitor C_1 through the diode D_2. When the voltage on C_1 reaches the upper triggering threshold, the Schmitt Trigger changes state and turns on the transistor T_3. This provides a current sink and essentially grounds the emitters of T_1 and T_2, causing D_2 to become reverse biased. The charging current I_1 now flows through D_1, T_1 and T_3

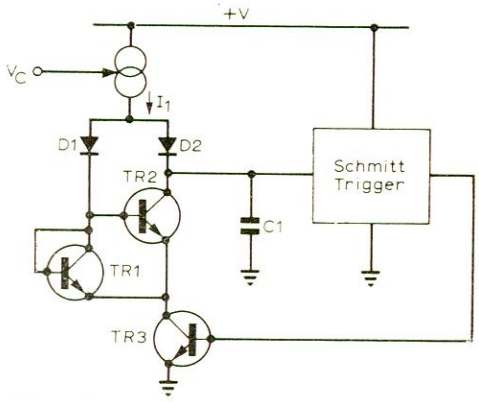


Fig 5.70. Simplified circuit diagram of the voltage controlled oscillator (vco).

to ground. Since the base-emitter voltage of T_2 is the same as that of T_1, and equal current flows through T_2. This discharges the capacitor C_1 until the lower triggering threshold is reached, at which point the cycle repeats itself. Because the capacitor C_1 is charged and discharged with the constant current I_1, the VCO produces a triangle waveform as well as the square wave output of the Schmitt Trigger.

The actual circuit is shown in **Fig 5.71**. The phase comparator is a double-balanced multiplier which mixes the input signal with the VCO square wave output.

The free-running VCO frequency is determined by both the size of the tuning capacitor and the magnitude of the charging current, and hence the VCO frequency can be made to be programmable by means of:

1. Switching to different capacitor values for C_1.
2. Changing the charging current by switching to different resistance values for R_1, injecting a current into pin 8, or externally controlling the voltage at pin 7.

The phase comparator also contains a diode limiter D_{12} and D_{13} which causes the lock range to be insensitive to the input signal level. The output of the phase comparator is then amplified by a differential amplifier T_{26} and T_{27} and filtered with the external filter capacitor C_2. The Phase Locked Loop is then closed by connecting this output back to the control voltage terminal of the VCO (base of T_1).

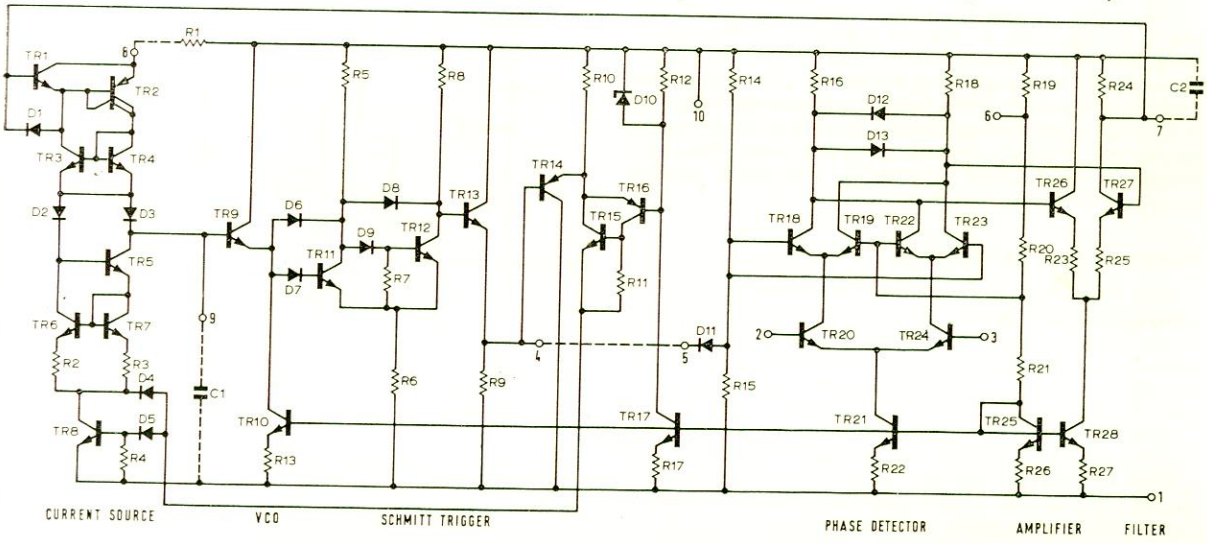
FM Demodulation

The 565 Phase Locked Loop is a general purpose circuit designed for highly-linear fm demodulation. During lock, the average dc level of the phase comparator output signal is directly proportional to the frequency of the input signal. As the input frequency shifts, it is this output signal which causes the VCO to shift its frequency to match that of the input. Consequently, the linearity of the phase comparator output with frequency is determined by the voltage-to-frequency transfer function of the VCO.

Because of its unique and highly linear VCO, the 565 PLL can lock to and track an input signal over a very wide range (typically $\pm$ 60 per cent) with very high linearity (typically, within 0·5 per cent).

A typical connection diagram is shown in **Fig 5.72**. The VCO free-running frequency is given approximately by $f_o = \frac{1}{4R_1 C_1}$, and should be adjusted to be at the centre of the input signal frequency range. C_1 can be any value, but R_1

Fig 5.71. Circuit diagram of the phase locked loop.



should be within the range of 2,000–20,000Ω with an optimum value of the order of 4,000Ω. The source can be direct coupled if the dc resistances seen from pins 2 and 3 are equal and there is no dc voltage difference applied between the pins. A short between pins 4 and 5 connects the VCO to the phase comparator. Pin 6 provides a dc reference voltage that is close to the dc potential of the demodulated output (pin 7). Thus, if a resistance (R_2 in **Fig 5.72**) is connected between pins 6 and 7, the gain of the output stage can be reduced with little change in the dc voltage level at the output. This allows the lock range to be decreased without affecting the free-running frequency. In this manner the lock range can be decreased from ± 60 per cent of f_o to approximately ± 20 per cent of f_o (at ± 6V).

A small capacitor (typically 0·001μF) should be connected between pins 7 and 8 to eliminate possible oscillation in the voltage controlled current source.

A single-pole loop filter is formed by the capacitor C_2; connected between pin 7 and positive supply, and the internal resistance of approximately 3,600Ω.

The input signal level can be between 1mV and several volts peak-to-peak, however, if the loop is to track wide frequency deviations, it is recommended that the input level be greater than 100mV peak-to-peak.

As previously discussed, the VCO consists basically of a voltage controlled current source charging and discharging the capacitor C_1 between the trip points of the Schmitt Trigger. This makes available a triangle waveform across the capacitor C_1 (pin 9) and a square wave from the Schmitt Trigger (pin 4).

Transistors T_{20} and T_{24} form a differential input to the phase comparator and require external bias. The dc level at the inputs (pins 2 and 3) should be equal and must be in the lower half of the total supply voltage range to allow proper operation of the phase comparator. If, for example, supply voltages of ± 6V are used with a ground reference in the centre, the dc voltage at the inputs should be approximately between ground and −4V. For cases in which only one supply voltage is used, the inputs can be referenced to an appropriate voltage obtained from a voltage divider connected between supply and ground.

The control voltage for the VCO (demodulated output at pin 7) is referenced to positive supply as is the voltage controlled current source in the VCO. When the VCO is operating at its free-running frequency, this voltage has typically a value of $0{\cdot}125V_{cc}$ below positive supply where V_{cc} is the total supply voltage applied across the circuit. Again, for example, if supply voltages of ±6V are used, the output voltage at pin 7 would typically be 1·5V below positive supply (or 4·5V above ground).

Frequency Shift Keying (FSK)

FSK refers to data transmission by means of a carrier which is shifted between two present frequencies. This frequency shift is usually accomplished by driving a VCO with a binary data signal so that the two resulting frequencies correspond to the "0" and "1" states (commonly called space and mark) of the binary data signal.

A simple scheme using the 565 to receive fsk signals of 1,070Hz and 1,270Hz is shown in **Fig 5.73**. As the signal appears at the input, the loop locks to the input frequency and tracks it between the two frequencies with a corresponding dc shift at the output.

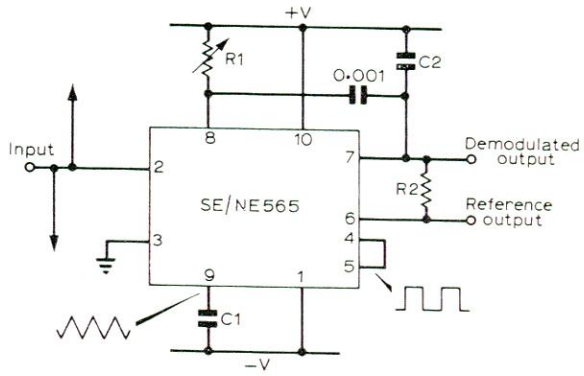


Fig 5.72. Phase locked loop typical connection.

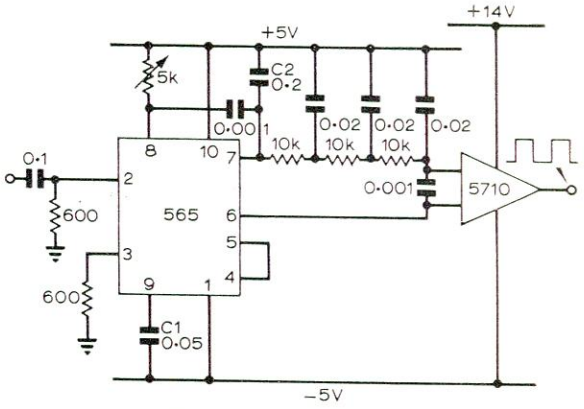


Fig 5.73. Fsk receiver using the NE565.

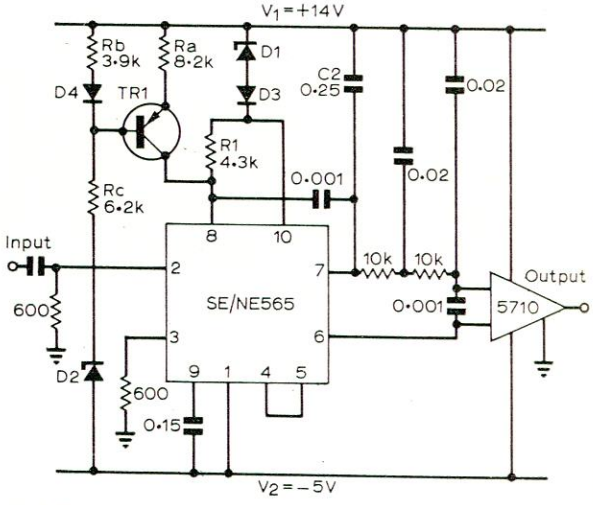


Fig 5.74. Narrow fsk receiver using the NE565. D1 is 6V zener; D2, D3, D4 are silicon rectifiers.

The loop filter capacitor C_2 is chosen smaller than usual to eliminate overshoot on the output pulse, and a three-stage RC ladder filter is used to remove the carrier component from the output. The band edge of the ladder filter is chosen to be approximately half-way between the maximum keying rate (300 baud or 150Hz in this case) and twice the input frequency (about 2,200Hz). The free-running frequency should be adjusted (with R_1) so that the dc voltage level at the output is the same as that at pin 6 of the loop. The output signal can now be made logic compatible by connecting a voltage comparator between the output and pin 6.

The input connection is typical for cases where a dc voltage is present at the source and therefore a direct connection is not desirable. Both input terminals are returned to ground with identical resistors (in this case, the values are chosen to achieve a 600Ω input impedance).

A more sophisticated approach primarily useful for narrow frequency deviations is shown in **Fig 5.74**. Here a constant current is injected into pin 8 by means of transistor T_1. This has the effect of decreasing the lock range and increasing the output voltage sensitivity to the input frequency shift.

The basis for this scheme is the fact that the output voltage (control voltage for VCO) controls only the current through R_1, while the current through Q_1 remains constant. Thus, if most of the capacitor charging current is due to T_1, the current variation due to R_1 will be a small percentage of the total charging current and, consequently, the total frequency deviation of the VCO will be limited to a small percentage of the centre frequency.

The circuit of **Fig 5.74** uses a 0·25μF loop filter capacitor to give approximately 30 per cent overshoot on the output pulse.

The output is then filtered with a two-stage RC ladder filter with a band-edge chosen to be approximately 800Hz (approximately half-way between the maximum keying rate of 150Hz and twice the carrier frequency). The number of stages on the filter can be more or less depending on the degree of uncertainty allowable in the comparator output pulse. Two small capacitors (typically 0·001μF) are connected between pins 8 and 7 of the 565, and across the input of the comparator to avoid possible oscillation problems.

For best operation, the free-running VCO frequency should be adjusted so that the output voltage (corresponding to the input frequencies of 1,070Hz and 1,270Hz) swings equally to both sides of the reference voltage at pin 6. This can be easily done by adjusting the centre frequency of the VCO so that the output signal of the 5710 comparator has a 50 per cent duty cycle. It is usually necessary to de-couple pin 6 with a large capacitor connected to positive supply in order to obtain a stable reference voltage for the 5710 comparator.

CHAPTER 6

AUXILIARY EQUIPMENT

POLARIZED RELAYS

POLARIZED relays are used in telegraph circuits for a number of purposes. The chief characteristic lies in the property to sense the direction of current flow within the operating coil, and convert this information into a switching action. For use at telegraph signalling speeds the relay must be capable of converting the input signal current direction to a switching action with the minimum possible delay and distortion. The contact arrangement of the polarized relay used in telegraph signalling usually takes the form of a single pole change over switching action. Input sensitivities are specified in ampere-turns or a minimum to maximum coil current operating figure. In circumstances where the sensitivity and operating current are not known, the following will give a guide to the requirements sufficiently accurately for normal use up to a signalling speed of 75 bauds.

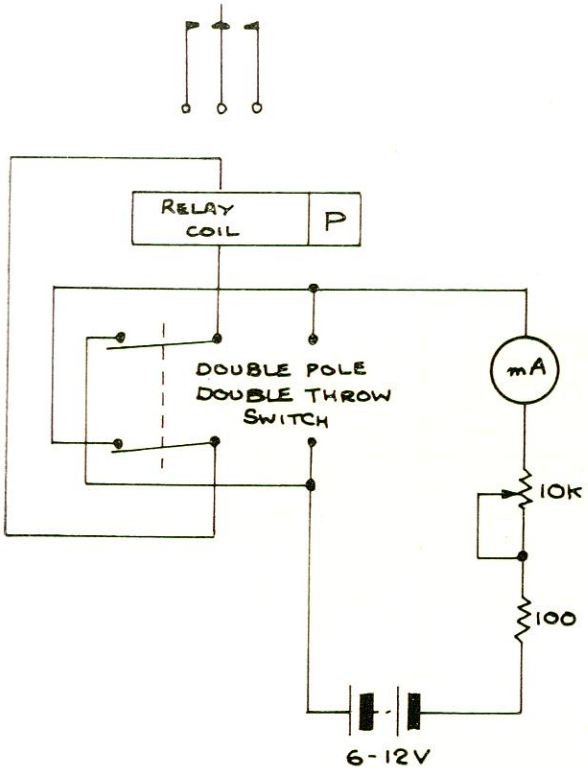


Fig 6.1. Test circuit to determine relay operating current.

Determine the coil connections and measure its resistance. Should there be more than one winding, select the one with highest resistance. Connect up the circuit shown in **Fig 6.1** with RV1 at maximum resistance. Slowly increase the current, at the same time operating the reversing switch, and note at what current the armature follows the switching action. Multiply the value of the current by four to give a rough approximation to the current requirements. This approximation will only hold good for a relay in reasonable adjustment, ie in a centre-stable relay the armature remains clear of both contacts with no current flowing, and similarly an each-side-stable relay armature remains on its respective contact when moved by hand. The coil current determined by the above method must only be taken as an approximation and not to be regarded as an optimum value for the ultimate in relay operating speeds.

The contacts of a polarized relay are made of materials suitable for various voltage ranges, with a specified mechanical contact loading and amount of slide. The following will give a guide to the user in the selection of the contact material.

Voltages in the mV Range

Minimum contact force: 30gm.
Contact material: hard gold alloy.
Contact slide: of the order of 0·0005in.

Voltages of 20V or Greater

In this case, immediately the tarnish film is cracked, a high resistance contact is made due to the heat produced by the voltage. Local melting occurs and the contact slides more easily, fracturing the film so that a lower contact force can be used.

Minimum contact force: 10gm.
Contact material: silver.
Contact slide: of the order of 0·0005in.

Telegraph Signalling Relays

Minimum contact force: 20–30gm.
Contact material: copper-palladium.
Contact slide: of the order of 0·0005in.

With this material, welding of the contacts is avoided and the impulse distortion, therefore, reduced to a minimum. This information makes the assumption that the relay is to be used with adequate protection of the contacts against excessive arcing.

Mercury wetted contact relays and solid state polarized

relays are considered under their respective headings.

The polarized relay may be used in a number of circuit applications and a few of these are considered.

When a teleprinter or receiving machine is to be connected to a long line with high loop resistance, it is often to be found that there is insufficient power to operate the selecting mechanism directly. A polarized relay may be connected across the line instead, with suitable series resistance and possibly shunted capacitor, such that it is operated at its optimum. The contacts are connected to a local voltage

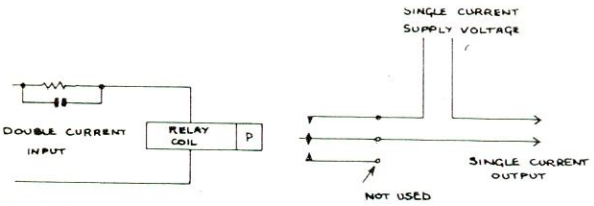


Fig 6.2. Double current to single current converter, without contact protection.

source and wired to the receiving machine so that the selector magnet is also operated at its own optimum condition.

Double current to single current signalling conversions are also often required, and this may be simply achieved by connecting the relay as shown in **Fig 6.2.**

Single current to double current conversions are a little more difficult in that they require the relay to have two separate windings, **Fig 6.3.** The second winding is required to apply a fixed bias to the relay armature in such a manner as to equalize the contact mechanical loading on either contact, irrespective of the *on* or *off* state of the single current input. A rough method of setting this current is first determine the line coil current under dc conditions and setting the bias winding current to half of this value, provided the two coils have the same number of turns. Fine adjustment to the bias current should be made under signal conditions for minimum distortion. This will entail the use of test equipment similar to that described in Chapter 9.

The final use of the polarized relay to be considered is in conjunction with valves or transistors for current conversion and isolation. Insulation resistance between coil and contacts may be as high as $10^{10}\Omega$ and a breakdown voltage level of 250V or higher. The operating currents are low enough to enable the relay to be used in conjunction with valves or transistors without difficulty. However the coil should be operated from a current source for optimum performance, meaning a high voltage supply and current limiting by a series resistor. Two examples are shown in **Fig. 6.4**, and in the case of the transistor circuit, the diode protection required for the transistor to be operated within its voltage ratings if the relay coil has any appreciable inductance.

Preventive Maintenance

Examining a relay known to be in good condition enables the user to recognize defects which will affect its operation. Extreme caution should be used when handling the relay so as not to damage or misalign the relay mechanism.

Relay Inspection

A relay may be considered to be in good condition if the following conditions are satisfied:

(*a*) The exterior is free from dirt or dust.
(*b*) The relay assembly is securely mounted.
(*c*) The relay coil shows no sign of overheating.
(*d*) The wire insulation is not frayed or torn.
(*e*) The connections to the relay are tight.
(*f*) The contacts are lined up and correctly spaced.
(*g*) The contact springs are in good condition.

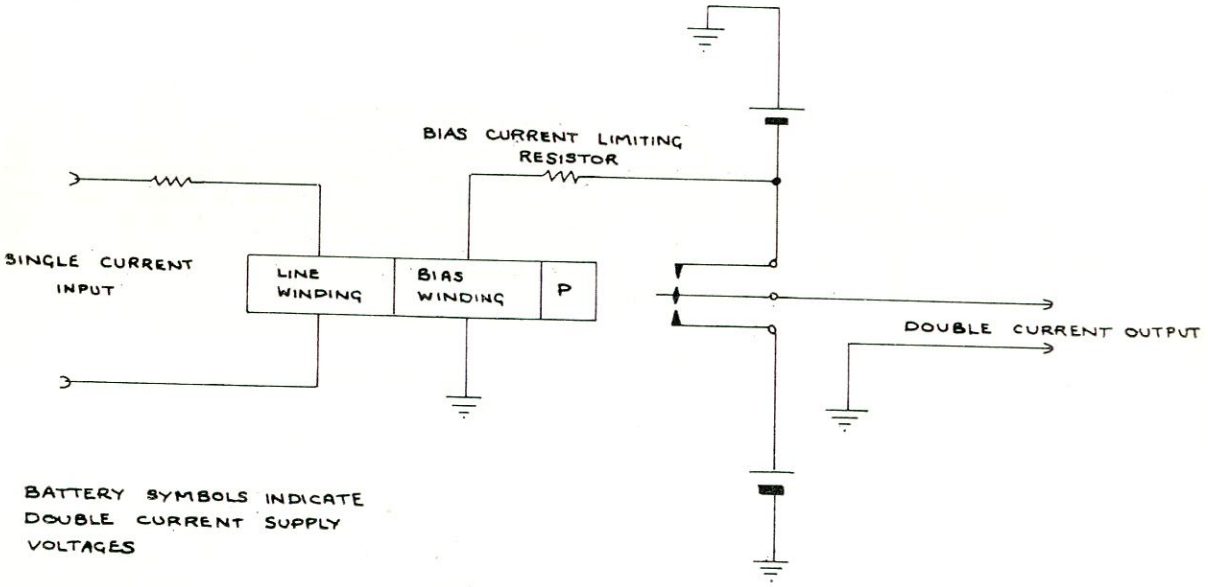


Fig 6.3. Single current to double current converter, without contact protection.

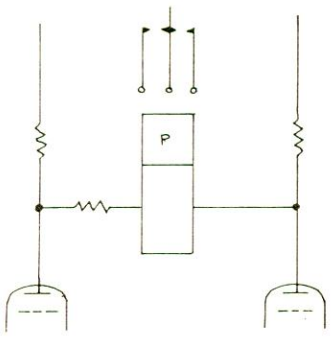
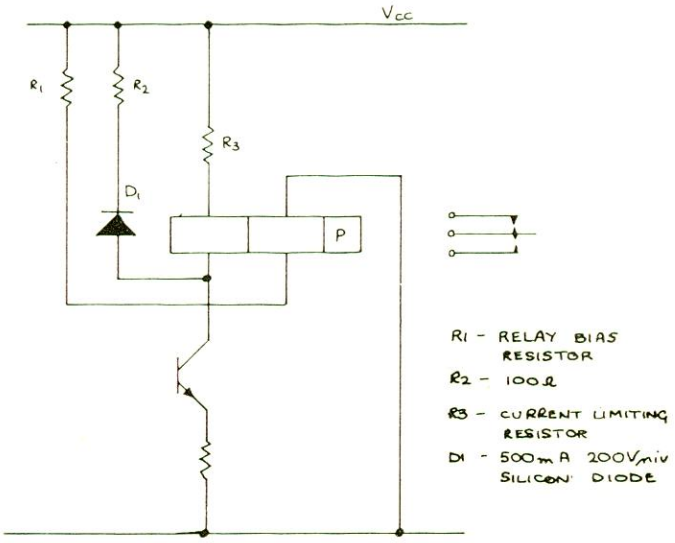


Fig 6.4. Relays used in conjunction with valves and transistors.



(*h*) The armature travels freely and functions satisfactorily.
(*i*) The contacts are not burned, pitted, or corroded.

Contact Protection and Interference Suppression

For long contact life it is essential that the contacts are protected against excessive arcing. When current is switched off in an inductive circuit, back emf is generated tending to maintain current flow. If the inductance is high, as in teleprinter selector magnets, this back emf is considerable and will cause severe arcing at the contacts. Arcing causes excessive contact wear, transferring material from one contact to the other. With the very small contact gaps in polarized relays this will gradually reduce the working gap and eventually a short-circuit will be the result.

The method used to avoid excessive arcing is to provide a low impedance local circuit across the contact gap with a capacitor and resistor. This may be achieved in two ways as illustrated in **Fig 6.5**. The single RC network may only be used when the voltage source is of low impedance. Values of R and C will vary for different circuit conditions, but the indicated values will be found suitable for most magnets.

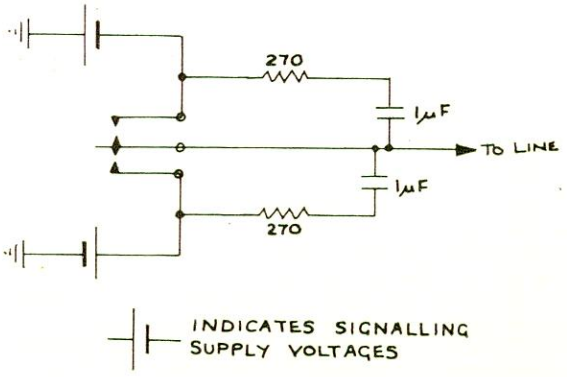
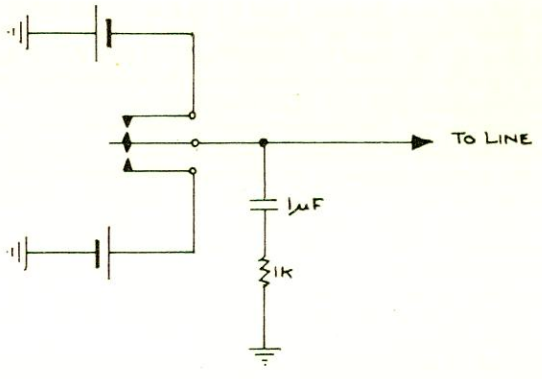


Fig 6.5. Relay contact arc suppression.

Interference suppression up to a frequency of 30MHz is best carried out as shown in **Fig 6.6**, with the components mounted as close as possible to the relay base. Above this frequency extra care will be needed in selection of the components, ie inductors with a low self capacity and capacitors with a low self inductance, components in a metal box each circuit individually screened.



CARPENTER TYPE 3

Introduction

The Carpenter Type 3 telegraph relay is manufactured in many forms to suit individual applications and requirements; including very high speed operating characteristics and a variety of bases on the next page. **Table 6.1** shows the type numbers and contact arrangements that are in common use. On some relays there are only minor mechanical differences between type numbers, eg Type 3M is identical to a 3E with the exception of the base; Type 3K is the same as a 3G but has no cover.

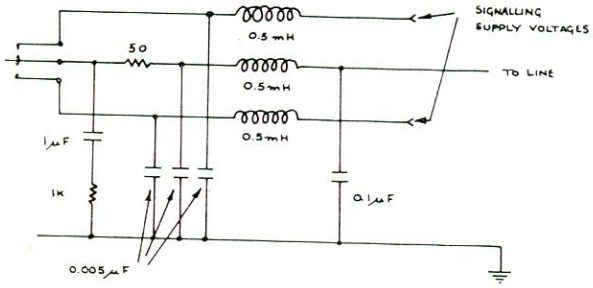


Fig 6.6. Relay contact interference suppression.

TABLE 6.1 Typical Carpenter relay Contact Arrangement and Type Numbers

Relay type code number	3E	3G	3H	3J	3K	3L	3M	3N	3P
Each side stable	√	√	√		√	√	√	√	√
Centre stable				√					
Insulated armature connection		√			√				

Operating speeds of the type 3 may vary, but in general the maximum upper limit is in excess of 400 bauds. Relay types 3E, 3G, 3K, 3M, 3N and 3P have a mechanical resonance at approximately 480 bauds where a bias of 5 or 6 per cent occurs. Above this speed the relay operates satisfactorily up to about 700 bauds. At these high speeds of operation, a much finer and more accurate adjustment is required than for the telegraph speeds of 45 or 50 bauds.

There are some 51 types of operating coils that may be fitted to the Type 3 relay, and details of the fitted coil will be found on the printed wrapper. Each coil has been allocated a code number by the manufacturer, and this code number usually appears on the relay case as a suffix to the relay type number. The coil number may be prefixed by a letter indicating the type of contacts fitted or other special features, eg P for platinum contacts, T for tungsten contacts and S for low-pass interference suppressors incorporated in the side contacts and armature connections.

General Care of the Relay

The relay must be treated as a sensitive instrument and handled with care. To ensure that it will give reliable service, the cover must not be removed except when periodic servicing or adjustment is to be carried out. Iron dust is the chief cause of incorrect operation and the smallest particle in the magnetic gaps will cause irregularity of working.

To prevent the formation of pips and craters on the contacts, they must be burnished at regular intervals depending on the service demanded of the relay. In amateur use a general rule would be once a year, provided the contacts are protected from excessive sparking. Burnishing may be accomplished by gently rubbing a clean, thin (approximately 2mil (0·05mm)) feeler gauge over the contact surfaces. If this precaution is not taken and pitting becomes excessive, it will be necessary to remove the contact assembly from the relay for reconditioning.

The mumetal core of the coil must be handled with care as any distortion will adversely affect its magnetic properties.

The magnets must not be allowed to come into contact with each other, nor with other magnetic materials, nor must they be handled with iron or steel pliers. Failure to observe these precautions will result in a reduction of the pole strength. If the magnets are removed from the relay, careful notes should be made of their position relative to one another. They should never be mixed with magnets from other relays of the same type as careful selection for the matching of flux densities was made during manufacture.

Particular care should be taken with relays fitted with suppressors to avoid damage to the suppression components.

Causes of Irregular Working

Irregular working is usually caused by:

1. The presence, in the working air gaps, of magnetic particles which must be removed by means of a piece of stiff, non-fluffy paper or high pressure dry air jet.
2. The tarnishing or slight roughening of the friction surfaces of the side contacts. These can be cleaned by passing a thin feeler gauge (about 2mil (0·05mm)) a number of times between the contact side springs and the friction screw on which it bears, care being taken to hold the gauge parallel with the rubbing surface of the spring.
3. Dirty contacts, which may be cleaned by burnishing as described in the comments on general care of the relay.

TABLE 6.2. Servicing Tools for relay maintenance

Tool	Quantity required	Use
Locking cam key	1	For cams A and B (Fig 6·7)
Spacing gauge (Fig 6·9)	2	Armature replacement on Type 3E, 3G and modifications
Spacing gauge (Fig 6·10)	2	Armature replacement on Type 3H and 3J relays
8mil (0·2mm) non-magnetic tongue spacer	2	For adjustment of pole faces gaps 1 and 2 (Fig 6·7)
0·03in (0·76mm) non-magnetic spacer	2	For adjustment of magnetic gaps 3 and 4 (Fig 6·7)
7BA box spanner	1	For lamination fixing nuts (33) (Fig 6·7)
4BA box spanner	1	For bias magnet locking nuts (39) (Fig 6·7)
Tension gauge or weights (2 and 3gm)	1	For contact spring pressures on Type 3H and 3J relays
Tension gauge 10 to 80gm	1	As above for relay Types 3E, 3G, etc
Various screwdrivers, adjusting pliers, etc		

Maintenance

A detailed description will be given for the maintenance of relays without suppression components fitted internally. For servicing relays with suppressors, extra care should be taken and careful notes made on any changes as and when it is required to remove the suppression components, to enable their correct replacement on re-assembly.

Coil Replacement

1. Loosen cams A and B **Fig 6.7**, and push out the mumetal core laminations from the coil, handling them carefully.
2. Remove the framing screw (44) making connection to frame, thereby freeing the armature connection lead.
3. Remove the two backplate fixing screws (42) and the backplate (41). The two base-locating pins (51 and 52), which secure the base to the relay frame, must then be unscrewed and removed from beneath the base.
4. Carefully ease the coil forward and fold back the relay frame until it lies clear of the base, taking care not

to damage the contact leads which pass up the back of the frame.

5. Unsolder the coil leads from the base tags and remove the coil. Connect short lengths of wire to the new coil and fit this coil into position.

6. Connect and solder the wiring to the tags and restore the relay frame to its original position.

7. Secure the base to the relay frame by means of the two locating pins. The large diameter pin (51) is inserted in the right-hand side when viewed from the front of the relay.

8. Replace the backplate (41), with the curved edge facing inwards, and make sure that the felt washer (40) is correctly positioned over the screw head of the bias magnet (35) to prevent entry of dust.

9. Secure the backplate by the two fixing screws (42).

10. Replace the framing screw (44), firmly connecting the armature lead to the relay frame.

11. Insert the mumetal core laminations into the coil with the edges lying on the cams A and B (**Fig 6.8**, item 49, shows how the laminations are stacked). Clamp the laminations in position by means of cams A and B, paying particular attention to ensure that the core is securely clamped but not mechanically stressed during this operation.

Reconditioning the Contacts

Badly pitted relay contacts can be reconditioned by careful filing. Work on the contacts must be carried out with the greatest care to avoid altering the contact spring friction pressures which are carefully adjusted during manufacture to ensure the correct degree of damping. The reconditioning procedure for the adjustable contacts (9) is as follows:

1. Loosen the contact locking screw (12), turn back the contact adjusting screw (8) so that the contact is well clear of the armature and then retighten the locking screw (12).

2. Remove the two block fixing screws (19) and the contact blocks (5 and 6), handling carefully the mica insulators and the screw insulating bushes which form part of the block assembly. Keep each assembly as a matched set of components.

3. Carefully run a very smooth, fine-cut file lightly over the contact surface until all the pips and craters are removed.

4. Finish by burnishing until the contact is smooth and polished.

5. Before replacing the contact adjusting screw and block assembly, the contact spring friction pressure must be checked with a tension gauge. The back of the contact spring tip, which bears on the friction screw (11), is very highly polished and this should be checked for cleanliness so as not to impede the smooth rubbing action.

6. The tip of the tension gauge should be applied to a point on the contact spring close to the friction screw (11), and at right angles to the rubbing surface of the contact spring. For the Types 3E and 3G relays and their various modifications (eg Type 3N1), this pressure must be adjusted to 50–52gm. For the Type 3H and 3J relays, the pressure is 2–3gm. If the pressure is less than these figures it can be increased by a small clockwise movement of the frction screw (11); pressure is reduced by a counter-clockwise movement of this screw. After adjustment, a small dab of locking paint should be applied to the screw head.

7. If the pressure differs appreciably from the stated figures, it must be adjusted for the necessary force at the root of the contact spring with a pair of narrow-bladed adjusting pliers. Great care must be exercised to avoid cracking the springs, and this must not be attempted if the pressure can be achieved by means of the friction screw (11). If this treatment is done as a last resort, check that the domed contact is not displaced from its central position on the axis of the screw.

8. Reassembly of the contact blocks is the reverse of the dismantling, making sure that the domed contacts of the contact block assembly are aligned with the contact on the armature. If it is found impossible to align the contacts, the incorrect number of mica insulators (14) have been fitted.

Reconditioning the Armature Contacts

1. Loosen both contact locking screws (12) and turn back both contact adjusting screws (8) so that the contacts are well clear of the armature. Retighten the locking screws (12).

2. Insert 3mil (0·76mm) thick non-magnetic spacers in the air gaps 3 and 4 **Fig 6.7**, between the magnets and the armature, to prevent them from touching and thereby reducing the pole strengths of the magnets.

3. Loosen the magnet clamping screws (24) and withdraw the two magnets (22) taking care that they do not touch each other or any magnetic material. The magnets must be stored separately in a place free from all magnetic dust particles until required for reassembly.

4. Remove the four outer suspension spring fixing screws (29) and washers (30), so enabling the armature (25) to be withdrawn.

NOTE: The Types 3G and 3K relays are fitted with an insulated armature contact system, and the pigtail connecting wire must be unsoldered from the armature tag strip before the armature can be removed.

5. Repair of the armature contacts is identical to that of the fixed contacts as previously described.

6. Replace the armature in the relay using the washers (30) and fixing screws (29). These screws should be left slack, allowing the armature to be moved within the limits of the elongated holes of the suspension springs (26 and 27).

7. To ensure that the armature is fitted exactly in the centre of the clamp bracket, spacing gauges must be inserted in the clamp bracket slots so that they lie on either side of the armature, beneath the suspension springs. The dimensions of these gauges, which may be made of brass or other non-magnetic material, are shown in **Figs 6.9** and **6.10**.

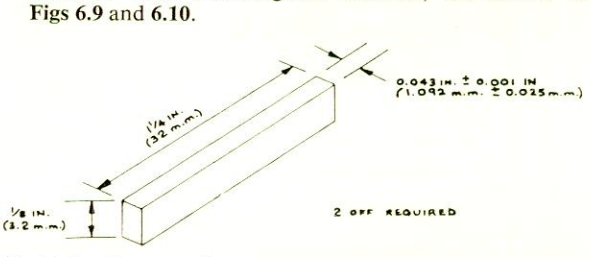
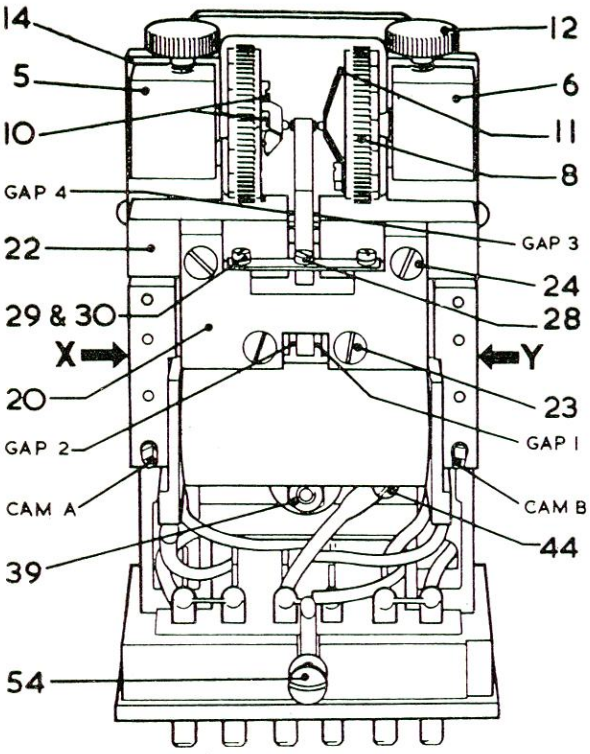
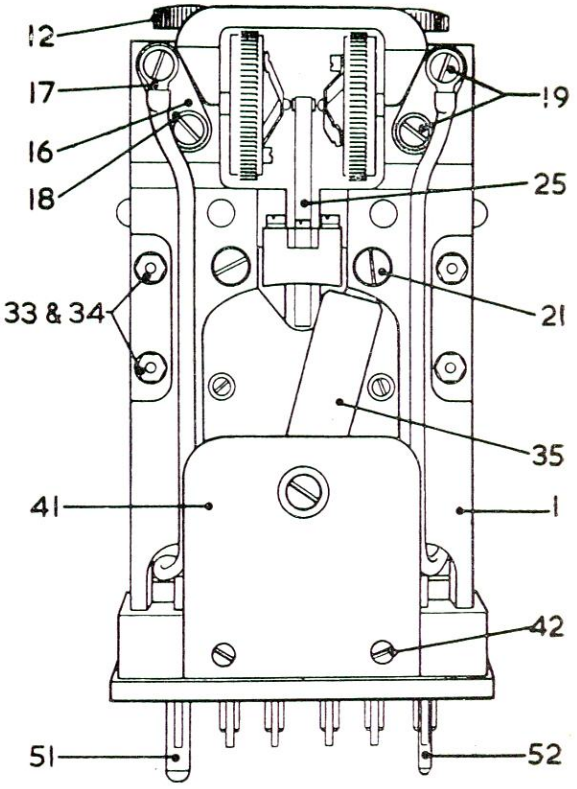


Fig 6.9. Spacing gauge for armature replacement. Relay Types 3E, 3G and modifications.



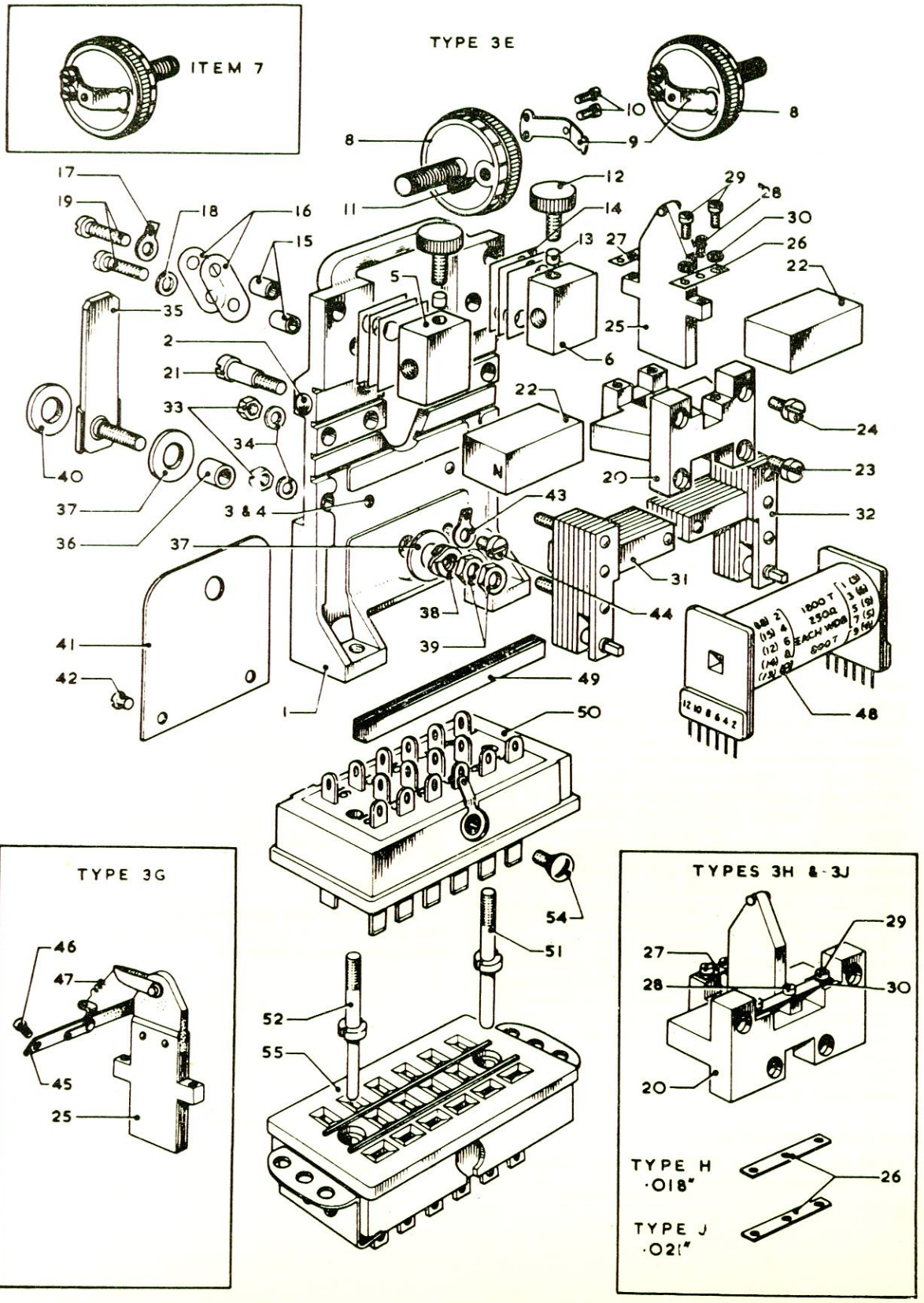
ABOVE: Fig 6.7. Front and rear view of Type 3 relay.



RIGHT: Fig 6.8. Exploded view of Type 3 relay.

Key to Figs 6.7 and 6.8

Item No.	Description
1	Mounting plate
2	Insulating studs
3	Bias magnet stop, washer
4	Bias magnet stop, fixing screw
5	Contact block, left hand
6	Contact block, right hand
7	Contact adjusting screw assembly
8	Contact adjusting screw
9	Contact spring
10	Contact spring fixing screw
11	Friction screw
12	Contact locking screw
13	Fibre locking pad
14	Mica insulator
15	Contact block insulating bush
16	Mica washer
17	Soldering tag
18	Metal washer
19	Contact block fixing screw
20	Clamp bracket
21	Clamp bracket fixing screw
22	Magnet
23	Lamination clamp screw
24	Magnet clamp screw
25	Armature
26	Armature suspension spring, front
27	Armature suspension spring, back
28	Armature fixing screw
29	Suspension fixing screw
30	Suspension fixing washer
31	Lamination, left hand
32	Lamination, right hand
33	Lamination fixing nut
34	Lamination fixing washer
35	Bias magnet
36	Magnet insulating bush
37	Magnet insulating washer
38	Spring washer
39	Magnet locking nut
40	Felt washer
41	Back plate
42	Back plate fixing screw
43	Framing soldering tag
44	Framing screw
45	Armature tag strip
46	Tag strip fixing screw
47	Tinned copper wire
48	Coil
49	Coil core laminations
50	Plug base
51	Locating pin, large
52	Locating pin, small
53	Cover (not illustrated)
54	Cover retaining screw
55	Socket


ITEM 7
TYPE 3E
TYPE 3G
TYPES 3H & 3J
TYPE H
·018"
TYPE J
·021"

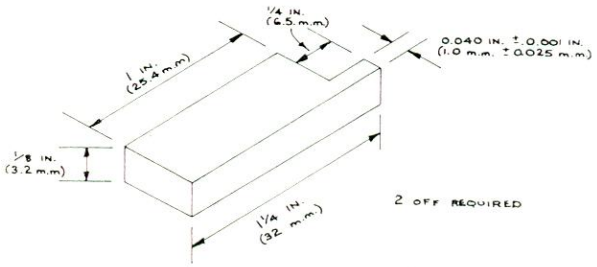


Fig 6.10. Spacing gauge for armature replacement. Relay Types 3H and 3J.

8. With the gauges in position, tighten the outer fixing screws (29) and withdraw the gauges.

Correct Symmetrical Assembly

1. Loosen the core clamping cams A and B, the four lamination fixing nuts (33) on the back of the frame, and the two lamination fixing screws (23) on the front of the clamp bracket (20).

2. Move the laminations slightly outwards and check that the armature hangs freely.

3. Move the bias magnet (35) to its upright central position.

4. Loosen the contact locking screws (12). Advance one contact adjusting screw (8) until contact is just made with the armature, and then turn it back about half a division of the scale on the adjusting screw. This adjustment is easiest to check with a battery and two low-voltage lamps, one connected to each contact.

5. Repeat the above operation on the second contact adjusting screw.

6. Insert 8mil (0·2mm) spacers between the armature and pole faces of the laminations (gaps 1 and 2) and gently move the laminations by gripping them between thumb and forefinger at points X and Y (**Fig 6.7**), until the armature contact is clear of both side contacts as indicated with the battery and lamps. Tighten the fixing nuts (33) firmly, and the clamping screws (23) fairly firmly. Tighten the core clamping cams A and B having regard as to the comments in section 11 of the coil replacement instructions.

7. Remove the pole face spacers and check that the armature is still clear of the side contacts. If it is not, readjust in the manner described.

8. Re-insert the 8mil (0·2mm) pole face spacer in gaps 1 and 2 and the 0·03in (0·76mm) gaps 3 and 4.

9. Re-insert the two magnets after cleaning and removing any magnetic particles. These can easily be removed with a piece of self-adhesive tape. The magnets should be inserted so that the N etched on the end visible on the outside end is farthest from the mounting plate. The magnets must be inserted in the same side of the relay as originally fitted and pushed in until they touch the spacers. They must be held tightly in position while the magnet clamps (24) are tightened to secure them.

Final Test and Adjustment

Detail of the method of telegraph relay adjustment is given in Chapter 9.

All relay testing should be done with the bias magnet (35) in its upright central position. It should only be used after the relay cover has been replaced for a final fine correction for residual bias due to the presence of the cover.

Ac test details for the Type 3 relay are given in **Table 6.3.**

TABLE 6.3

Ac Relay Test Data

Coil drive signal 50 or 60Hz sine wave.
Figures quoted as ampere-turns

ie Coil current (rms) = $\frac{\text{ampere-turns}}{\text{number of turns on coil}}$

Relay type code number	3E, 3G etc	3H	3J
Non-operate	1·0	—	—
Just operate	1·7	0·4	0·2
Operate	3·6	2·0	2·0
Saturated	36·0	20·0	20·0

CARPENTER TYPE 4

The Type 4 relay has larger armature and side contacts than the Type 3, giving longer contact life. They are medium speed, sensitive relays originally designed for long distance dc and dialling circuits where high contact forces, large contact gap and ease of adjustment are essential. These relays will operate satisfactorily without attention for long periods of time without contact bounce or serious bias, at speeds up to 200 bauds.

The relay armature and side contacts form a single pole changeover unit which is available in either an each-side-stable (Type 4H) or one-side-stable (Type 4J) adjustment. The coding of coil and contact materials remains the same as that of the Type 3 relay.

Physically the Type 4 relay is slightly smaller than the Type 3, and there is no adjustable bias magnet for fine neutrality setting after the cover has been fitted. In its place is an internal magnetic shield above which the contacts may be adjusted with the external cover removed. It will be noticed from the photograph of the Type 4 relay that the compliant mounting of the side contacts is different, otherwise the construction is similar to the Type 3.

Adjustment

The alignment and adjustment of the Type 4 is similar to that of the Type 3. Contact gap should be 3–5mil. Ac test details are shown in **Table 6.4.**

TABLE 6.4

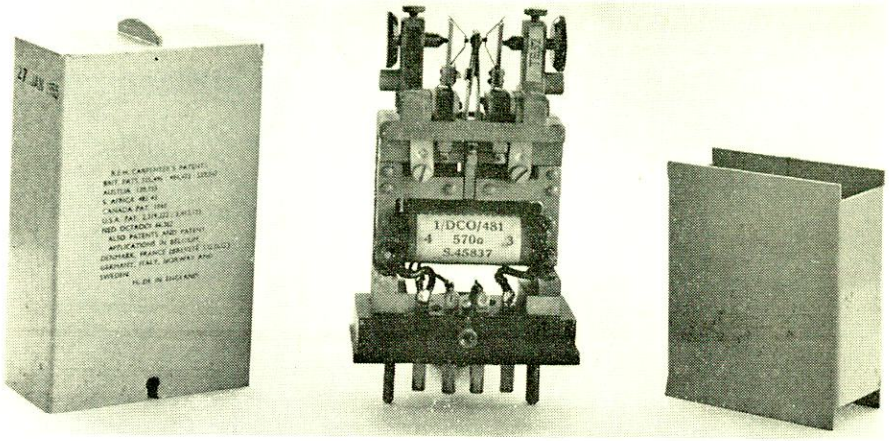
Ac Relay Test Data

Coil drive signals 50 or 60Hz sine wave.
Figures quoted as ampere-turns

ie Coil current (rms) = $\frac{\text{ampere-turns}}{\text{number of turns on coil}}$

Relay type code number	4H	4J
Just operate	4·5	14
Operate	8·0	25

Fig 6.11. Carpenter type 4 relay.



CARPENTER TYPES 5 AND 6

The Carpenter Types 5 and 6 telegraph relays are of a robust, compact construction of small volume. The principle of operation remains the same as the Carpenter Type 3 but the mechanical layout is totally different as will be seen by reference to **Fig 6.12**. Both types of relay are available in the each-side-stable or one-side-stable configuration and with plug, tag or flying contact lead bases together with various contact materials and coils. **Table 6.5** shows the parameters for optimum operating conditions. The Type 6 relay has greater armature travel than the Type 5, permitting a highly stable, centre-stable or one-side-stable form.

To ensure that the relay will continue to give reliable service, the cover should be removed only when periodic maintenance or adjustment is carried out. Iron dust is the main cause of inefficient operation, and the smallest particle in the magnetic gaps will cause irregular working.

To prevent the formation of pips and craters on the contacts, they should be burnished by gently rubbing a clean 5mil (0·13mm) feeler gauge over the contact surfaces whenever the relay is opened for adjustment. Where the contact loading is heavy, frequent burnishing may be necessary. If the pitting has become excessive it will be necessary to remove the contacts for reconditioning as described below.

Cover Removal (Fig 6.12)

With the tag-based relays, the cover can be pulled off without difficulty. In the case of the plug-based relays, the two cover retaining screws (2) must be loosened before withdrawing the cover carefully from the relay.

The sealed versions of the relay require the removal of the two clamp screws and plate from the top of the cover. The cover may then be pulled off.

Side-contact Assembly Removal

To remove a side-contact assembly having a forked hinge spring, loosen the two hinge spring fixing screws (13) to the extent of one or two turns and carefully remove the side contact assembly (18) by holding the contact spring backing plate and sliding the assembly from its mounting. Do not remove the hinge spring fixing screws or loosen them more than necessary. On relays where the hinge spring is provided with holes instead of a "fork", the two screws (13) must be removed together with the various insulators (10), clamp plate (11) and guide plate (15). The side contact assembly may then be lifted off the relay.

Reconditioning the Contacts

Badly pitted relay contacts can be reconditioned by careful filing with a smooth fine-cut file over the contact

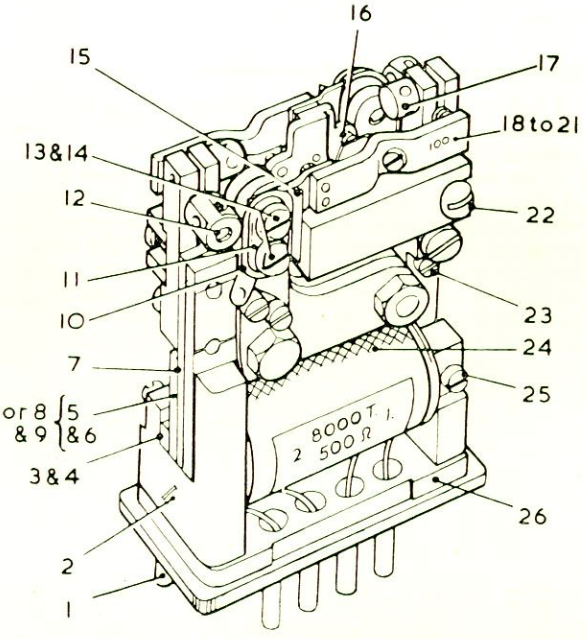


Fig 6.12. Type 5 relay. For part identification purposes it may be assumed to represent the Type 6 relay.

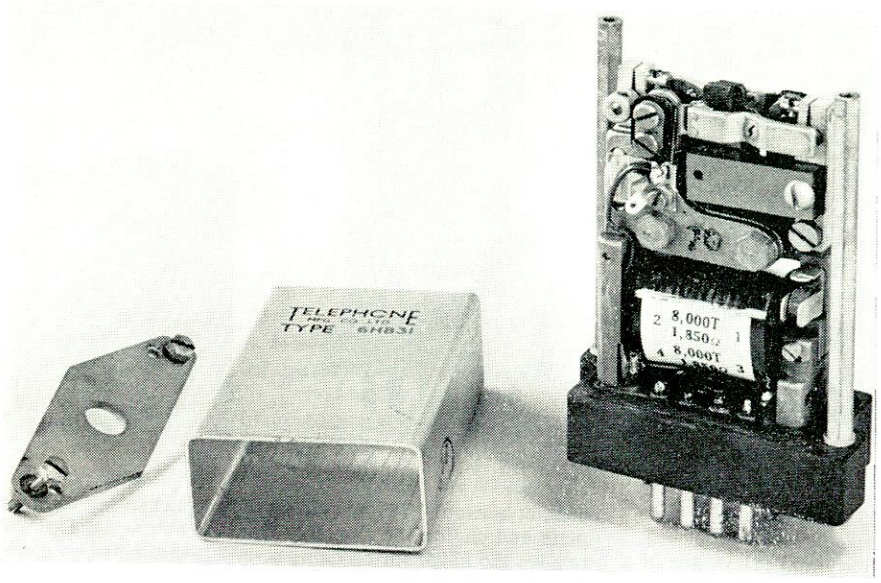


Fig 6.13. Type 6 relay.

surfaces until all the pips and craters are removed. Finish by burnishing until the contact is smooth and polished.

When filing the armature contacts, care must be taken to avoid damage to the suspension system, and it is essential to support the contact end of the armature. After reconditioning the contacts it is advisable to rub a 5mil (0·13mm) feeler gauge over the tip of the friction screw. The side contact friction pressures are carefully adjusted during manufacture to ensure the correct degree of damping, and any work on the contacts must therefore be carried out with the greatest care to avoid altering these pressures.

Side Contact Assembly Replacement

Fit the side contact assembly to the relay, taking care that insulators (10), clamp plate (11) and guide plate (15) are replaced in the order removed.

If the hinge spring is of the "forked" type, place a 5mil (0·13mm) feeler gauge between the head of the contact adjusting screw and the hinge spring assembly to prevent the prongs of the fork from being pushed through and making electrical contact. During this operation care should be taken to see that the forks of the hinge spring pass beneath the guide plate (15) with the centre prong between the two insulator bushes through which the two fixing screws (13) pass. Lightly re-tighten the two screws (13). Check that the contact on the side spring assembly is accurately aligned with the armature contact and fully tighten the two fixing screws (13). Remove the feeler gauge and check the insulation resistance between side contacts and frame is satisfactory.

Armature and Pole-piece

The replacement operations on the armature and pole-piece assembly are of a difficult and skilled nature and it is vital that the armature be suspended without stress and exactly in the centre of the pole-piece gaps. Since incorrect centering will lead to unsatisfactory performance of the relay with varying levels of energization, it is inadvisable to attempt the removal of any components other than that required for contact overhaul.

Final Test and Adjustment

Details of the method of telegraph relay adjustment are given in Chapter 9.

Dc test details may be taken from **Table 6.5**, the ac adjustment being carried out with a coil energization of up to 4·0A turns rms 50Hz.

TABLE 6.5

Type		5A Each side stable	5H Each side stable	5M Centre stable	6B Centre stable	6U Each side stable
Operate energization	nominal	2·5AT	7·6AT	2·0AT	5·75AT	9·0AT
	min. circuit	7·0AT	11AT	6·0AT	10AT	12AT
Contact force	unenergized	4·5gm min	16gm min	—	—	14gm min
	min. circuit	12gm	40gm	6gm	9gm	30gm
Switching frequency		0–100Hz	0–100Hz	ac only	0–100Hz	0–100Hz
Power loading of coil		1W maximum				

WESTERN ELECTRIC 255A AND 215A (Fig 6.14)

Introduction

The 255A and 215A polarized relays are mechanically similar and have two separate coil windings. The dc resistance of each coil on the 255A is 136Ω and the 215A 90Ω. 255A relays may have the part number D163119A marked on its cover or frame. The 255A relay is easier to adjust owing to its more accurate construction and hence capable of adjustment for a higher sensitivity. These relays may be adjusted to be centre-stable or each-side-stable.

Fig 6.15 shows the general layout of the relay together with the plug base connections.

Maintenance

The interior and exterior of the relay cover should be wiped clean with a lint-free cloth, and any dust or lint removed from the relay contacts with a soft bristle brush.

Inspect the relay contacts thoroughly. If they are dirty, burned, pitted or corroded, service them in accordance with the following instructions.

NOTE: The brown discoloration found on silver or silver-plated contacts is silver oxide and a good conductor. It should not be removed unless the contacts must be cleaned for some other reason. It may be removed at any time either by burnishing or by rubbing with a cloth moistened with carbon tetrachloride.

To clean contacts, use a thin (about 2mil) flat feeler gauge or contact burnisher. Keep the blade clean by frequent wiping with a lint-free cloth moistened with carbon tetrachloride. To burnish the contacts, press them together with a toothpick or operate the relay manually to give a slight pressure against the back of the burnisher. At the same time move the blade back and forth two or three times or as often as necessary to brighten the contacts. Avoid excessive burnishing, as when too much material is removed readjustment will be necessary. If burnishing does not eliminate the contact trouble use carbon tetrachloride to clean the contacts more thoroughly. Do not rub the contacts but apply the carbon tetrachloride to the contacts with the aid of a toothpick, taking care not to allow any to come into contact with the insulating materials used in the construction of the relay. Always burnish the contacts after cleaning with carbon tetrachloride.

Contact points which are badly pitted may be reconditioned by removing the build-ups with a fine-cut point file. Burnish the pits with a ball-point burnisher. If the pit is small, place the ball-point burnisher in the pit and rotate the burnisher between finger and thumb. If the pit is large, move the point of the burnisher over the surface of the pit with a circular motion.

A ball-point burnisher may be made from an old scriber as follows: with the aid of a fine oilstone, remove the point until the diameter is approximately 0·02in and then form a hemispherical end. Polish the hemisphere by rotating the end of the scriber in a piece of hard wood or zinc block, using

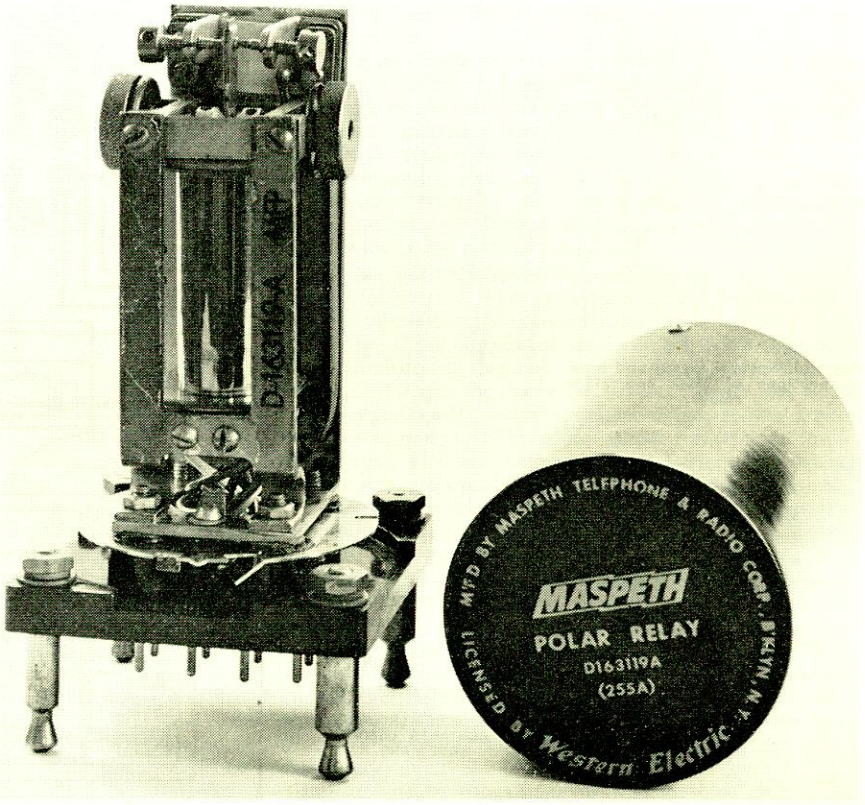


Fig 6.14. 255A relay.

metal polish as a cutting agent. Finally polish the end on a piece of leather with the aid of french chalk.

After removing build-ups and cleaning pits, again burnish the contacts with a flat blade contact burnisher.

CAUTION: Never use highly abrasive materials such as sandpaper or emery cloth to clean relay contacts. Do not use paper to clean contacts as minute burrs on the contact surface may retain fine shreds of paper and cause faulty contact operation.

Adjustment

Preparation

Remove any particles adhering to the armature or pole-piece screws by pressing a fresh piece of self-adhesive tape wrapped around a piece of thin, stiff, non-magnetic metal against the particles. Do not rub the tape against the armature or pole-piece screws as this rubbing will leave a residue which will collect further particles.

Make sure the pole-piece screws and relay terminals are clean.

Requirements

The armature should not touch the inside of the coil.

The contacts should align so that the centres of the contacts will not be out of alignment by more than 25 per cent of the contact diameter.

The armature contact springs should be parallel to the armature. The tips of the armature contact springs should rest against each other approximately flat across their width with a pressure of 1–2½oz measured on one spring at the contact with the other spring held firmly in the neutral position. If necessary back off the contact screws for this check.

In its normal unoperated position, the clearance between the armature and either contact screw should be approximately equal and when the armature is held against one contact there should be 3–5mil clearance between the armature and other contact screw.

When the armature is held first against one contact and then against the other, the armature stop pins should not touch the pole-piece screws.

The armature should be centred in the magnetic field between the pole-piece screws; that is, the armature must float in the gap between the contact screws or stay against either contact with approximately the same pressure when moved by hand.

Adjustments

Loosen the screws holding the coil to the relay frame and position it so that the armature is clear on its inside. Tighten the screws.

Loosen the armature clamping screws and position the

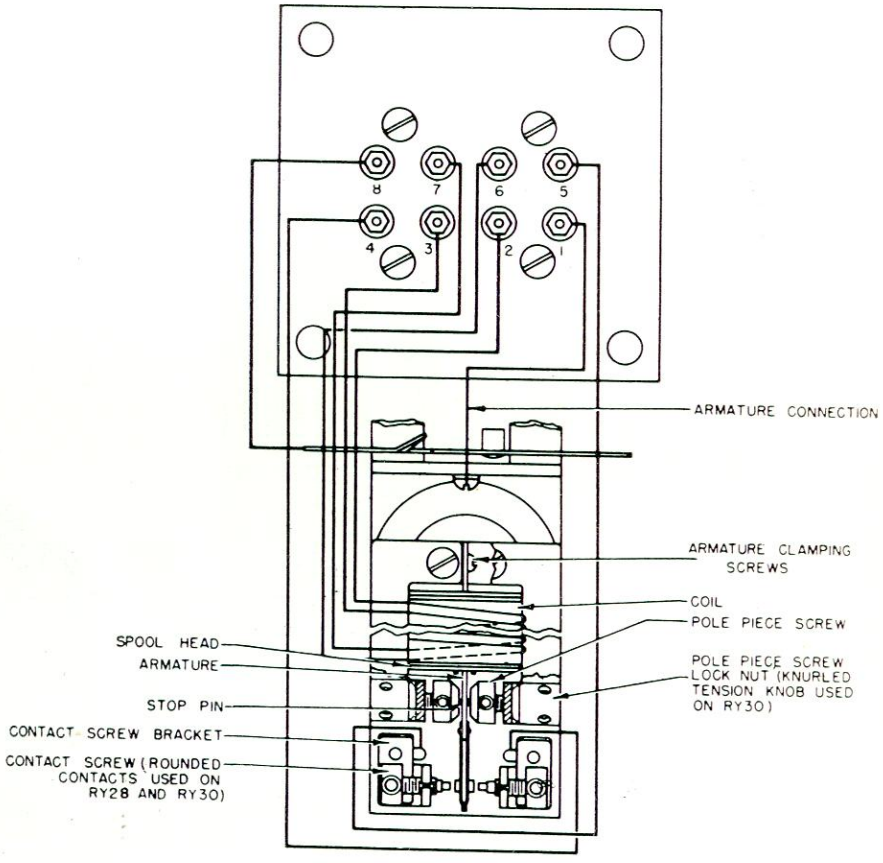


Fig 6.15. General layout and base connections of 255A and 215A relays.

armature both vertically and horizontally for best contact alignment and retighten the screws.

NOTE: To aid in aligning the armature contacts the contact screw brackets may be positioned by means of the enlarged mounting holes in the relay frame.

Bend the armature contact spring towards or away from the other armature contact spring as required to obtain the 1–2oz pressure as mentioned in the list of requirements. Bending must be done with extreme caution, and close to where the contact spring is riveted to the armature. Reset the contact screws to their former position.

Back off the pole-piece screws as far as possible and position the contact screws such that they are each 1·5–2·5mil clear of the armature.

NOTE: The contact screws should be sufficiently tight in their brackets to hold any adjusted position. If necessary remove the contact screw from the bracket and force the two halves of the split end of the bracket together to meet this requirement.

Advance the right pole-piece screw until, with its locknut (or knurled tension knob) tight, the right pole-piece screw pushes the armature far enough to just touch the left-hand contact screw. Back off the right pole-piece screw approximately a quarter turn from this position until the armature stop pin is clear of the pole-piece screw.

Advance the left pole-piece screw until the armature is centred in the magnetic field as described in the list of requirements.

Final adjustment of bias neutrality may be obtained with the aid of a relay test set as described in chapter 9. Fine adjustment of the left pole-piece screw being the only requirement. Any increase or decrease in the contact gap will decrease or increase the sensitivity and also affect the transit time of the armature. Care must be taken at all times to prevent the armature stop pin touching its respective pole-piece screw.

This setting up procedure will give the 255A relay side stable properties, ie the armature will always be resting on one contact screw. If the right pole-piece screw is backed off a half to three-quarter turn the left hand pole-piece screw may be adjusted for a centre stable relay, ie with no current flowing in the coil windings the armature will be clear of the contact screws.

MERCURY-WETTED CONTACT RELAYS

Mercury-wetted contact relays offer a combination of high speed, high current and voltage handling capacity with uniformity of performance over long periods of time which make them suitable for high-speed switching devices and applications which demand accuracy and dependability of the highest order. The relays have no bounce or chatter and do not become contaminated. If used with suitable protection the contacts will not stick or weld, and the Elliott relays are suitable for applications in which the product of the current and voltage does not exceed 250 provided that the voltage does not exceed 500 and the current 5A.

The contact assembly is sealed in a glass capsule filled with ultra-dry hydrogen at a pressure in the order of 200lb/in^2. Platinum contact surfaces are wetted with mercury which, when switching action is taking place, is continuously renewed from the reservoir by capillary action.

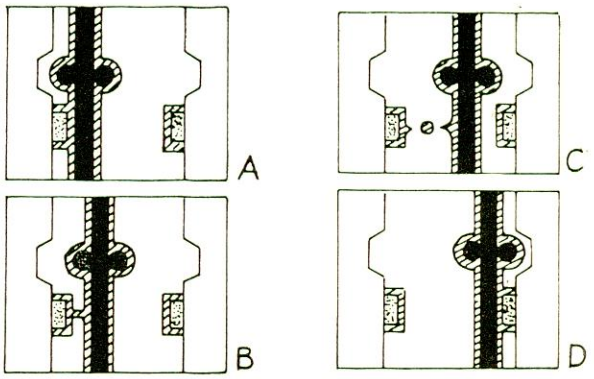


Fig 6.16. Mercury-wetted contact relay action, break before make.

Mercury-wetted contact relays are manufactured in various forms, the most suitable for telegraph signalling being polarized with a break before make switch action. The magnetic layout of the relay is shown in chapter 1, **Fig 1.24** and the contact operation of the break before make switch capsule is shown in **Fig 6.16**, described below.

A. Mercury (shown hatched) covers armature and contact faces.

B and C. As armature moves from open to closed position, mercury filament breaks before new contact is made in a break before make action. Ruptured mercury surfaces accelerate away from each other at estimated 1,500g's providing rapid breaking action.

D. Contact surfaces join, mercury wetting dampens rebound, eliminates chatter and provides uninterrupted metallic contact. Similar actions occur when the relay is operated in the reverse direction.

Contact life expectancy is based on the use of proper contact protection. This protection should be installed as close as possible to the relay terminals.

The R—C arc suppressor shown in **Fig 6.17a** is suitable for most switching demands. The values of R and C can be determined from the formulae or the contact protection nomograph **Fig 6.18**. (NOTE: Capacitance may be increased as much as 10 times to help reduce voltage transients of inductive loads.) For low values of load current and source voltage the resistor may be eliminated, **Fig 6.17b**; this arrangement is not suitable for high level telegraph signalling circuits. An alternative arrangement, and to be recommended for use with teleprinter selector magnets having a high inductance, is the arrangement shown in **Fig 6.17c** where the main R—C suppressor R_1–C_1 is placed across the load, but this may result in a condition which exposes the contacts to voltage transients having a rate of rise in excess of 5V/μs maximum. A secondary arc suppressor R_2–C_2 must then be included across the contacts. R_1–R_2 should be the calculated value. C_1 may be increased by 10 times the calculated value to reduce transients. C_2 need only be one-hundredth of the calculated value.

Diodes and varistors may be used in some circuits for

protection purposes, these being used in conjunction with, but *not* instead of, the R—C arc suppressor.

The purpose of the R—C arc suppressor is not only peak transient control, but to control the rate of rise of voltage across the contacts when the load circuit is opened.

Mercury-wetted contact relays must be mounted in a vertical position as indicated on the outer case. The mounting position may deviate up to 30° from the vertical with negligible change in operating characteristics.

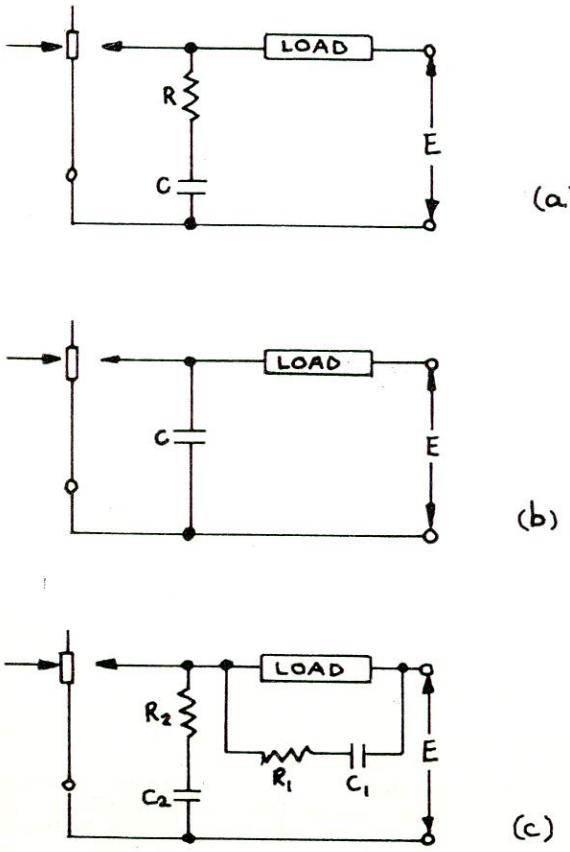


Fig 6.17. R—C arc suppression.

6—0—6 KEYING

The following selection of circuits are intended for use with any low-level telegraph equipment that is, or may become, available in the amateur shack. They may also be used in their own right as a system, each circuit being a building block.

The following units are described:

1. Double current teleprinter magnet driver: to convert 6—0—6 signal levels to a high level double current for driving a selector magnet. Maximum polar output current ± 20mA.

2. Single current teleprinter magnet driver: to convert 6—0—6 signal levels to an on-off current source at high level and suitable for use with a holding or pulling selector magnet. Maximum output current 60mA.

3. 6—0—6 keying source: to eliminate transmitter contact bounce and define the 6—0—6 signalling parameters. Suitable for use with double or single current-transmitting contacts by a change of input circuit. An alternative method for use with double current transmitting contacts is to use a zener diode regulated supply of ±6V in place of the 80—0—80 supply used in high level circuits, but contact bounce will not be eliminated and the output rise and fall times will not be defined.

4. Four input keying mixer: to automatically select any one of four sets of transmitting contacts, ie if any one of the inputs goes to space condition the output will follow. May be defined as an OR gate.

5. Telegraph operated relay: to turn on the transmitter as soon as telegraph signals are applied to the input and off after a period of approximately 4s after the last character. This unit is not suitable for use with teleprinters which are regenerative, as incoming signals appear on the transmitting contacts (see below).

Power supply requirements for each of the circuits are ± 18V with the addition of a +80V supply for the magnet drivers. Low-level signal inputs require approximately 1mA (I sink = 1mA) and the output circuits of line drivers are capable of supplying up to 10mA of drive current. In all the circuits with a low-level input the level should be defined at either + or −6V. Convention is +6V for the mark condition and −6V for the space.

Double Current Teleprinter Magnet Driver (Fig 6.19)

Transistors TR2 and TR3 form a bistable switch, and in conjunction with the emitter follower TR1 the input conditions are defined. Input hysterisis is approximately ±0·5V centred about zero, eg if an input change from +6V to −6V occurs at the input, the bistable will change state when the input is at −0·5V during the transition and similarly for an input change from −6V to +6V the change will occur at +0·5V. To modify the switching levels the ratio of the two input resistors may be changed.

Two output transistors TR5 and TR6 with a collector supply of 80V are emitter coupled with TR6 driven from TR5 via an emitter follower TR7. This arrangement ensures that only one of the output transistors will be turned on at any time. The polar teleprinter magnet is connected between the two output transistor collector resistors with a 5kΩ 10W variable resistor RV1 to set the magnet current to that recommended, usually 20mA. The direction of current flow in the teleprinter magnet is determined by which of the output transistors are turned "on", eg if TR5 is "on" and TR6 "off", current will flow through the magnet coil via R2 and conversely if TR5 is 'off" and TR6 "on" the direction of coil current will be opposite and via R1. Emitter follower TR4 links the bistable to the output stage, link c-a being changed to c-b if opposite keying sense is required. Protection of the output transistors is provided by the two 1N914 diodes 50μF capacitor and the 10kΩ-33kΩ potential divider.

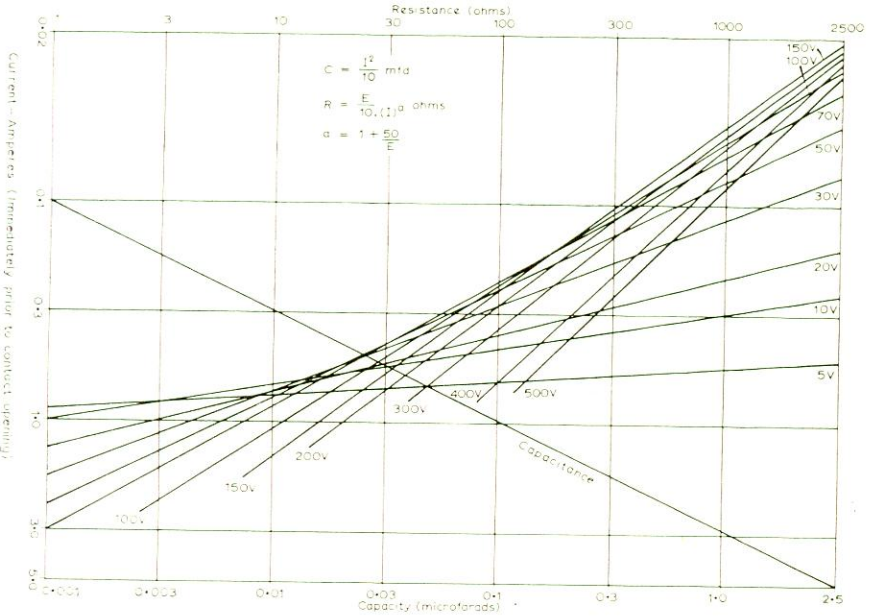
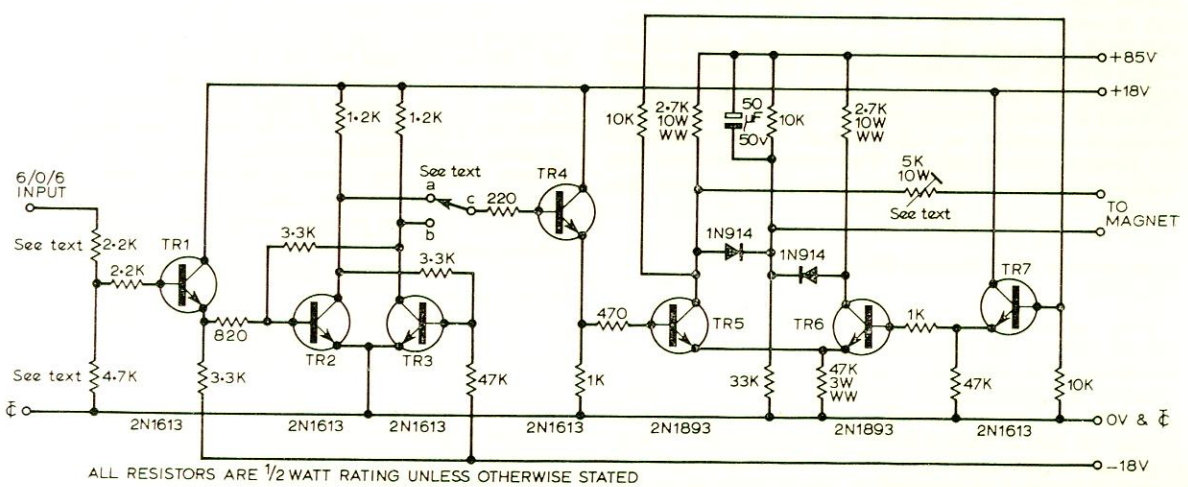


Fig 6.18. Nomograph to determine necessary contact protection of mercury-wetted contact relays.

Single Current Teleprinter Magnet Driver (Fig 6.20)

The input circuit is identical to that of the double current unit with an output circuit consisting of a simple two-transistor current amplifier TR4 and TR5. TR5 is an emitter follower with the selector magnet coil in series with the emitter and becoming the emitter resistor. A small, general-purpose power diode is across the coil to remove the back emf from the coil and a 68kΩ resistor in parallel to protect TR5 should the load be disconnected. To set the recommended coil current, a 5kΩ 10W variable resistor RV1 is in series with the output. With the link between the bistable, TR2 and TR3, in the position shown, a–c, TR5 will be turned "on" when a +6V level is at the input. If the reverse is required the link must be connected between b–c as is required when a pulling selector magnet is fitted to the teleprinter and +6V on the input indicates the mark position.

Fig 6.19. Double current teleprinter magnet driver.



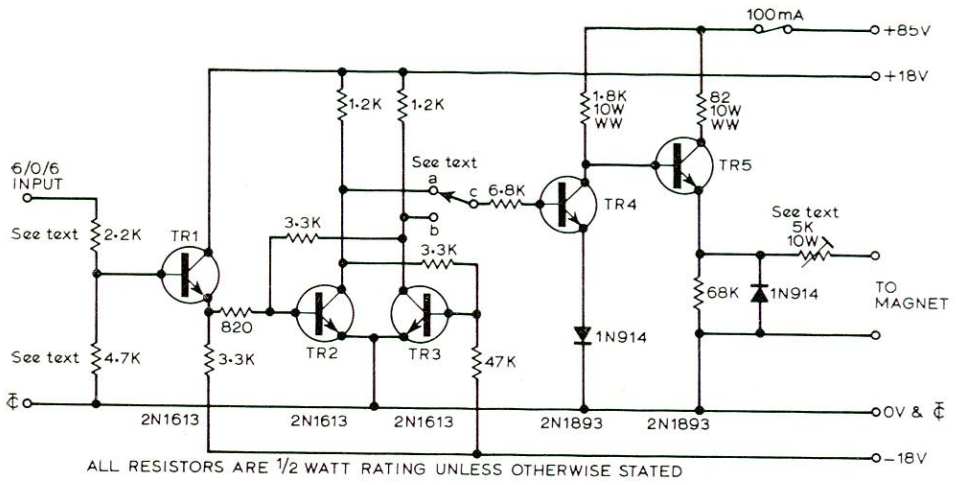


Fig 6.20. Single current teleprinter magnet driver.

6—0—6 Keying Source (Fig 6.21)

The input circuit is modified as compared with the two previous units and arranged to have the teleprinter transmitting contacts connected directly to the unit. Approximately 10mA is passed through the contacts to assist in breaking down any oil film and tarnish that may be present on the contact surfaces. It should be noted that when using a machine for the first time on low-level signalling the contacts should be carefully cleaned and burnished. Alternative input circuits are shown for double or single current keying contacts. The output of the bistable stage TR2 and TR3 is linked to an inverter TR4, the output of which is used to turn "on" or "off", TR5. The potential at the collector of TR5 will be approximately +6·6V if TR5 is "on" and −6·6V with TR5 "off". The level is defined by the 1N914 diodes and 5·1V zener diodes with about 250Ω in series. The potentiometer RV1 is available to balance the output voltage around zero from the class B output stage TR6 and TR7. 56Ω resistors are placed in each emitter of the output transistors to protect them from any possible short on the output line. The 4μF capacitor between the output and zero volt line is to increase the rise and fall times of the signals sufficient to prevent ringing due to line inductance and also reduce the possibility of radio receiver interference should the screening be inadequate. For normal operation with +6V as the mark condition link b–c and for −6V as mark link a–c.

Four Input 6—0—6 Keying Mixer (Fig 6.22)

Four identical input circuits similar to that used in the magnet drivers are connected to a four input OR gate comprising TR4, TR5, TR6 and TR7. To enable the bistable input to be defined at all times a single-pole changeover switch S1 is installed at the input of each circuit. The output of the OR gate is used to drive the output circuit which is identical to that used in the 6—0—6 keying source. The input circuit may be arranged to accept either + or −6V as the mark condition but the output will be 6V for mark. For a positive in and positive out signal link points a–c and d–f as shown. Negative in and positive out requires that the links be changed to b–c and e–f.

6—0—6 Telegraph Operated Relay (Fig 6.23)

This unit is to enable the transmitter on-off switching to be controlled from the keyboard. The output of the teleprinter transmitting contacts, with positive mark and negative space, is connected to an emitter follower TR1 with the output adjustable via RV1 to set the trigger level. With a +6V input, the collector of TR2 will be at approximately 7·8V (6·8V + Vce sat of TR2) thus charging the 47μF capacitor to about 7V.

Transistors TR3, TR4 and TR5 form a Schmitt Trigger circuit, the output being inverted by TR6 to operate the relay RLA in the collector of TR7. On the receipt of a negative pulse (space) at the input, TR2 will be turned "off" and the collector potential will rise to about 17V, thus charging the 47μF capacitor and also turning "on" TR3, changing the state of the Schmitt Trigger and operating the relay. When the input returns to +6V (mark) the capacitor will discharge via the 100kΩ resistor and the input to TR3. The Schmitt Trigger will revert to its original state when the voltage has discharged to approximately 5V, thus releasing the relay, this time duration being approximately 4s after the last negative input pulse (space) of the transmission. The minimum duration of any negative input signal is about 5ms to fully charge the 47μF capacitor. To force the transmitter "off" the push button PB1 will rapidly discharge the capacitor. To set the input switching level, RV1 should be adjusted such that the voltage on the base of TR2 is 7·5V with the input open circuit.

By the addition of a relay RLB with normally closed contacts at point X, the output of TR2, the unit may be interlocked with the receiving terminal unit in such a way that if tones are being received the relay will operate and

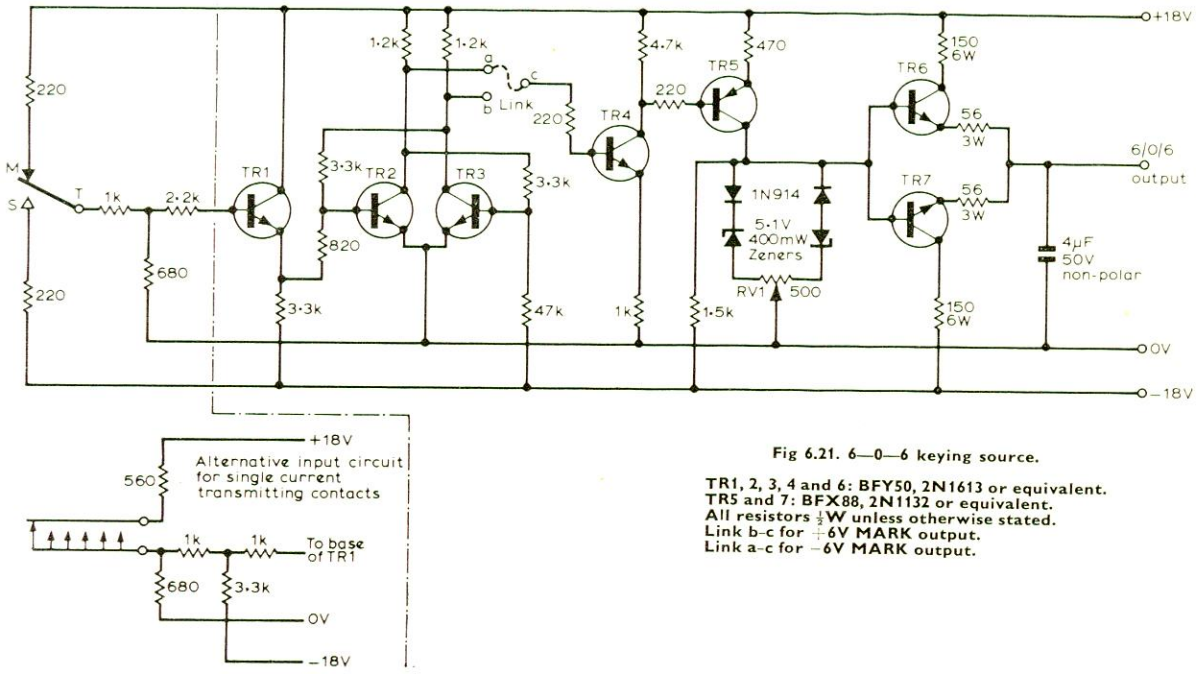


Fig 6.21. 6—0—6 keying source.

TR1, 2, 3, 4 and 6: BFY50, 2N1613 or equivalent.
TR5 and 7: BFX88, 2N1132 or equivalent.
All resistors ¼W unless otherwise stated.
Link b–c for +6V MARK output.
Link a–c for −6V MARK output.

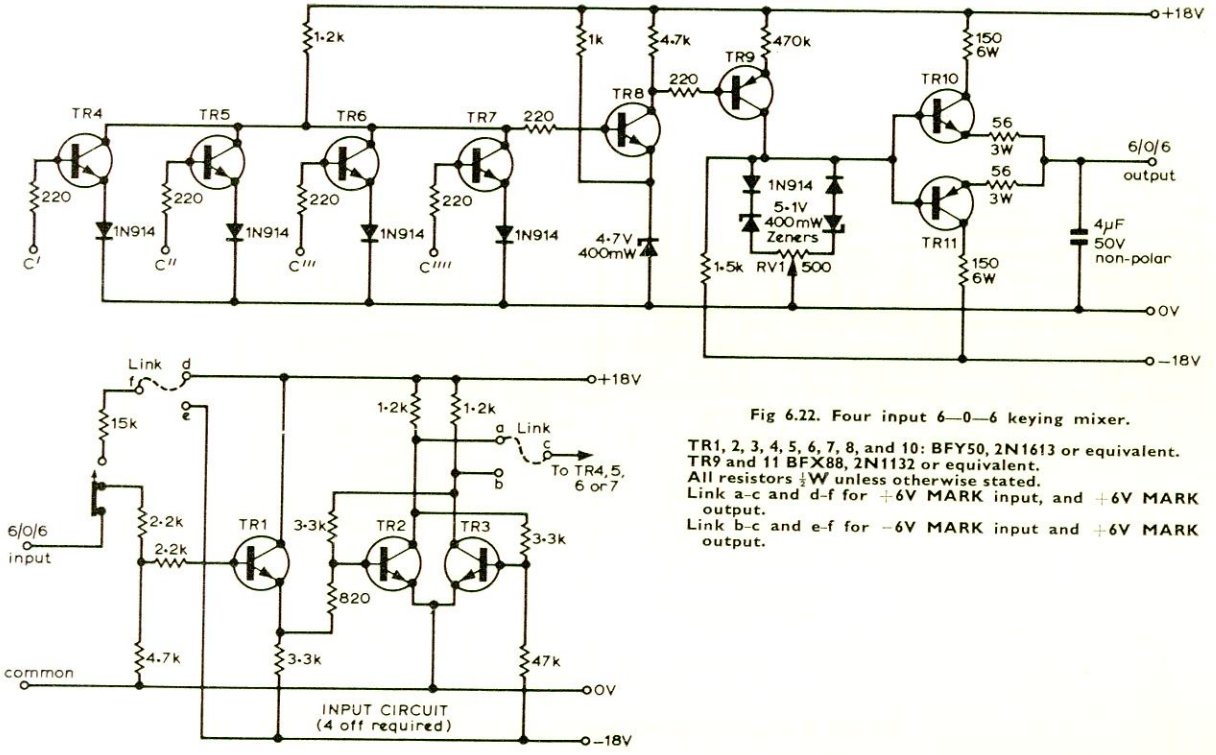


Fig 6.22. Four input 6—0—6 keying mixer.

TR1, 2, 3, 4, 5, 6, 7, 8, and 10: BFY50, 2N1613 or equivalent.
TR9 and 11 BFX88, 2N1132 or equivalent.
All resistors ¼W unless otherwise stated.
Link a–c and d–f for +6V MARK input, and +6V MARK output.
Link b–c and e–f for −6V MARK input and +6V MARK output.

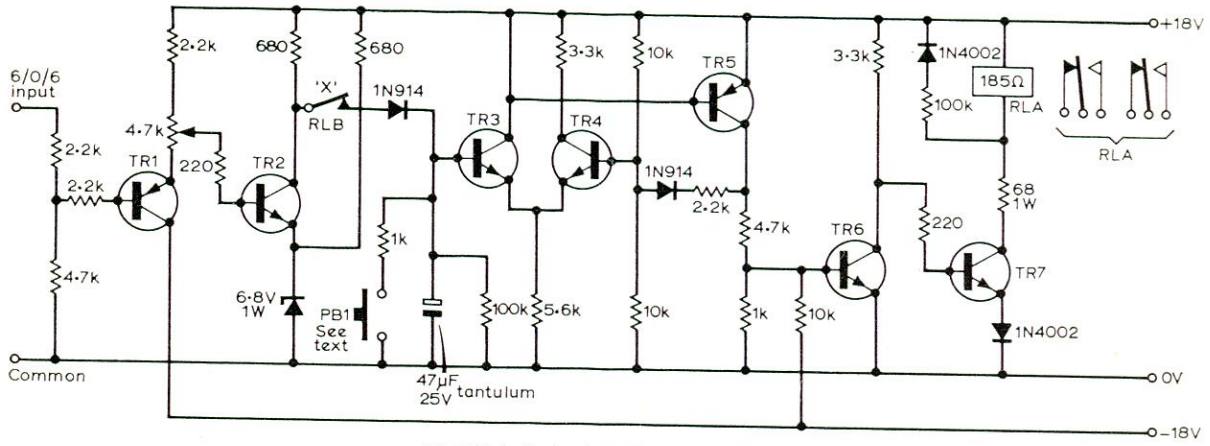


Fig 6.23. 6—0—6 telegraph operated relay.

prevent the capacitor being charged and thus keeping the transmitter in the "off" condition.

A typical amateur station layout is shown in **Fig 6.24**. Obviously the system must be built to suit individual requirements and hence the use of the above circuits as simple building blocks. Should the teleprinter being used be of the regenerative type, eg Creed 75, the transmitter contact output must be wired through the send-receive switch, and the switch adjusted correctly such that the transmitting contacts have come to rest before the switch reverts to the receive position. The telegraph operated relay RLA turns the tone oscillator on and off to activate the vox circuit in the transceiver. An inhibit output from the terminal unit will be required to prevent the system oscillating under certain conditions, the inhibit signal being used to operate relay RLB in the telegraph operated relay module.

The method of construction may be either printed circuit boards or pin board depending on taste. It must be noted that the wire-wound resistors get very hot and care will have to be taken as to the positioning of these relative to the other components.

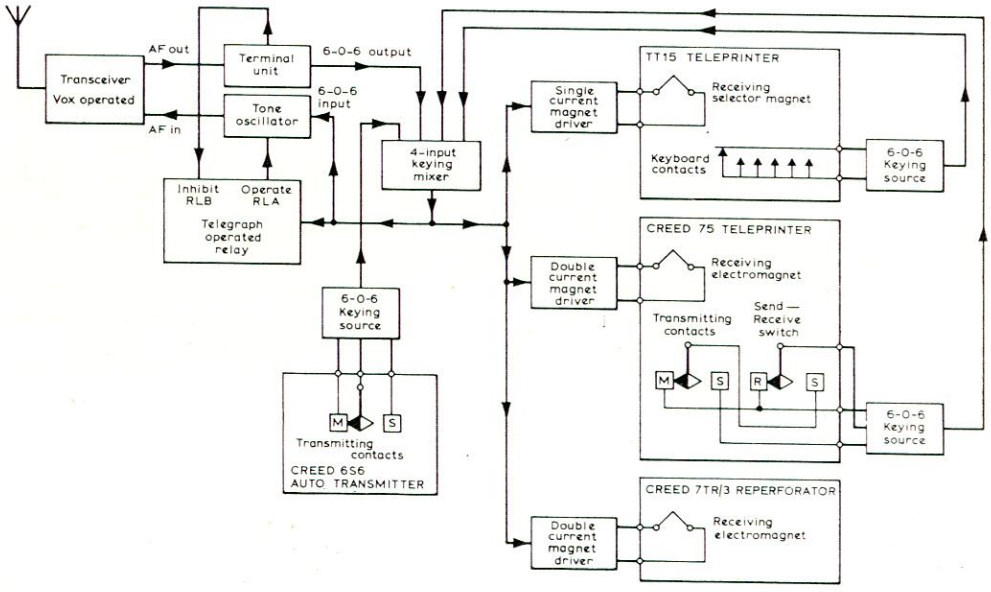


Fig 6.24. A practical low-level signalling layout for the amateur station.

A SIMPLE WAY TO MAKE A 7B GOVERNOR DUAL SPEED

Looking at the governor it will be noticed that on the block holding the fixed contact there is a 4BA tapped hole $\frac{5}{16}$in away from the contact, **Fig 6.25**.

Cut a piece of $\frac{1}{16}$in (approximately) steel $\frac{5}{16}$in by $\frac{3}{4}$in and drill a 4BA clearance hole $\frac{1}{4}$in from one end. Then cut a piece of insulated material, eg PCB without the copper, the same size with the hole in the same position.

Taking a 1in 4BA cheesehead screw, first put a large washer on, then a light compression spring (about four turns), then put the metal plate on followed by the insulated material. Add one or two nuts—to space the strips away from the block. Some governors use two full nuts and others one full and one half nut.

Screw the assembly gently into the existing tapped hole so that the two plates can be swung round, either over the moving contact, thus giving extra pressure, or 180 degrees away to leave the contact with its normal pressure applied.

Set the governor up for 45·5 bauds with the plates away from the contact, then swing the plates over the moving

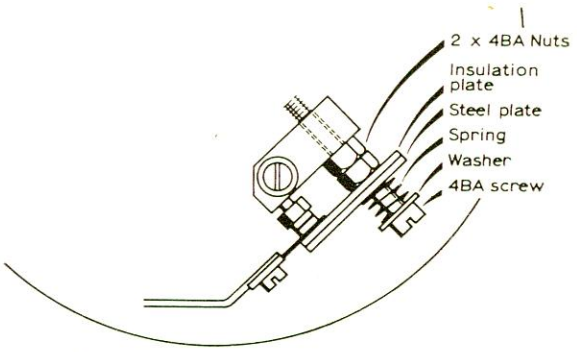


Fig 6.25. Speed control system block diagram.

contact and adjust the pressure on top of the contact with the screw to 50 bauds. Then lock the nuts tightly and re-check the 50 bauds speed.

Once this is done it is a simple matter to change speed by swinging the plates either over the contact or completely clear of the contact for either speed.

This method has been used successfully for many months and has not called for any readjustment. A piece of card with one side marked 50 bauds and the other 45·5 bauds is displayed under the clip on the front of the machine to indicate at which speed the machine is set.

ELECTRONIC SPEED CONTROL

Introduction

Although the electronic motor speed control now to be described was designed for Creed No 7 teleprinters it should be applicable equally well to any other teleprinter equipped with a governor controlled motor.

By substituting an electronic speed control for the governor two important advantages are achieved. Sparking contacts, which often are a persistent source of radio interference, are done away with, and the motor speed can be varied in a convenient way.

Any control system requires a means to measure the quantity to be regulated. Contrary to common practice no tachometer generator is used here to measure the speed because the installation of such a device involves severe mechanical problems which cannot be solved adequately by the average amateur. Instead the speed is determined from the repetition period of a pulsed signal generated by an easy-to-build optical system.

In the electronic circuit four inexpensive digital ICs are used to perform functions which otherwise would involve a large number of discrete components. As a result the construction becomes an easy matter.

The system is of the on-off type. As to stability and accuracy of speed regulation the results are better than those obtained with a governor or tachometer control.

General Description

The electronic speed control is a closed negative feedback loop as is apparent from the block diagram of **Fig 6.26**. **Fig 6.27** depicts the wave shape of a number of signals at various locations along the loop.

A speed signal, ie a signal which reflects the rotation speed of the motor, is generated as follows. A disc D connected to the motor shaft is provided with a number of holes evenly spaced along the circumference of a circle whose centre coincides with the rotation axis of the motor. When the motor is running the holes pass one after another between an incandescent lamp I and a photosenstive device P. Consequently the output signal of P is a series of pulses whose repetition period T is inversely proportional to the rotation speed and the number of holes.

After being processed by the shaper these pulses toggle the divider flip-flop. The output signal C and its complement C′ are applied to the respective reset and set input terminals of the comparator. These signals are square waves whose 0 and 1

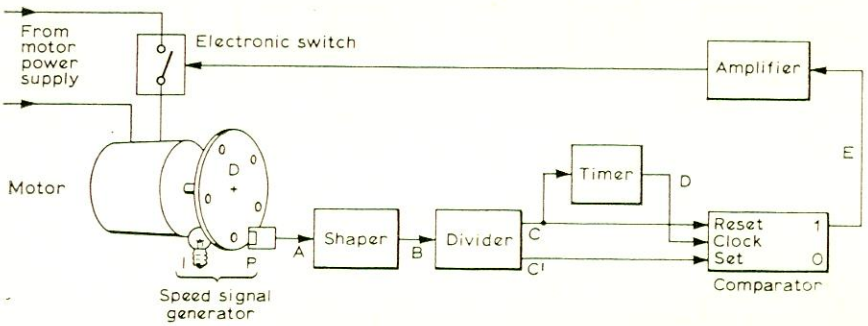


Fig 6.26. Creed series motor governor two-speed modification.

times are equal to T. At each positive-going voltage step at C the timer one-shot multivibrator is triggered upon which it generates a pulse of duration T_s (D). This pulse is applied to the clock input terminal of the comparator.

The latter is a JK flip-flop. Its state can change only as a result of a negative-going voltage step at the clock terminal, ie at the end of each timer pulse. The state to which the flip-flop will go depends upon the voltage levels at the set and reset terminals, as indicated in **Table 6.6**.

The last two conditions included in **Table 6.6** cannot occur here since the set and reset levels are complementary. It is seen that the output level of the comparator reflects the result of the comparison of T with T_s and hence the duration of the speed deviation.

TABLE 6.6

Input levels at the moment the clock pulse is applied		Output level after application of the clock pulse	
Set (C′)	Reset (C)	Output 1 (E)	Applies when:
0	1	0	$T > T_s$ (Speed low)
1	0	1	$T < T_s$ (speed high)
1	1	unchanged	—
0	0	reversed	—

The output signal of the comparator is amplified to operate an electronic switch which controls the power supplied to the motor in such a way that the speed error is counteracted. Thus the speed is regulated at the value for which $T = T_s$. Obviously, by acting upon T_s the speed can be set to any desired value.

This speed control system is inherently discontinuous. Speed errors are detected at every other hole of the disc and the correcting action lasts until the completion of the next error detection cycle. To obtain smooth operation the time required for two holes to pass must be much shorter than the combined electrical and mechanical time constant of the motor. It was found that this condition is amply satisfied with five holes in the disc. Drilling more holes is therefore not likely to be rewarded with a noticeable improvement and may even degrade the performance of the system because with more holes the percentage hole spacing errors will be greater.

Fig 6.28 shows the circuit diagram up to the amplifier. The design of the electronic switch will vary according to the motor type and to whether the motor is supplied with ac or dc. The terminal connections of the ICs are shown in **Fig 6.29**.

Speed Signal Generator

The repetition period of the speed signal pulses is given by the following expression:

$$T = \frac{60000}{N \times A} \text{ (ms)}$$

where N = number of rev/min

A = number of holes in the disc

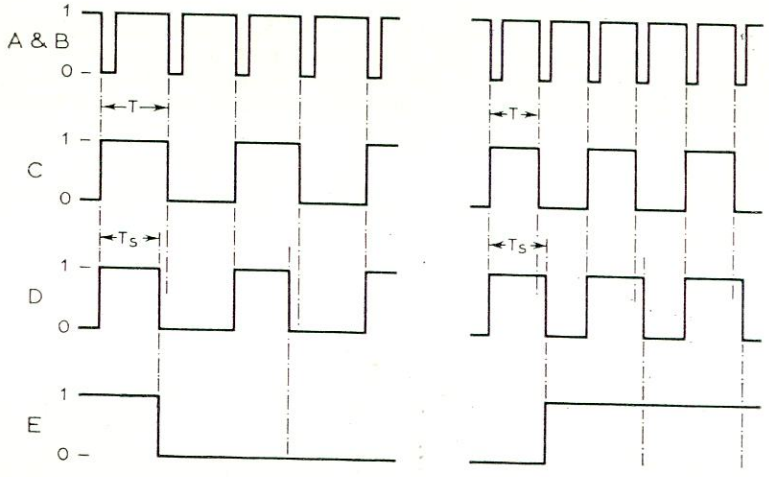
For N = 3,000 rev/min at 50 vauds and A = 5, T is 4ms at 50 bauds and 4·4ms at 45·5 bauds.

The correct spacing between the holes must be carefully maintained as the accuracy of the speed regulation depends on it. Taking into account that absolute perfection cannot be realized it is advisable to use an odd number of holes. Then the system will always work in identical conditions irrespective of at which hole the first error detection cycle starts when the circuit is turned on.

The size and shape of the holes is not important. Only the leading (negative-going) edge of the pulses is used. The disc can of course be smaller than **Fig 6.26** might suggest and instead of the disc a star-shaped device will do equally well.

The photosensitive device is an old-fashioned glass encapsulated pnp germanium transistor OC 71 (Q1) of which the black paint is partly removed to make the semiconductor chip visible. For greatest sensitivity Q1 must be as close as possible to the bulb I_1. When the distance is 1cm Q1 still goes solidly to bottoming with the light of a 7V 0·1A bulb operating at 4V. If a npn transistor is used for Q1 the circuitry to the left of the points X and Y must be reversed.

The bulb is the least reliable part of the system and should be mounted in such a way that it is accessible for replacement.



Left:
Fig 6.27. Speed control system waveforms

Parts list Fig 6.28 (opposite page):
(Resistors are 1/4W unless specified otherwise)
Q1: "peeled" OC71; see text
Q2, Q3: NPN silicon planar epitaxial transistors BC109C; P_{max} = 300mW; H_{FE} = 400 to 800
IC_1, IC_3: Fairchild μL914
IC_2, IC_4: Fairchild μL923
D1: bridge rectifier BY122; 42V 0·6A
D2: 3·3V, 400mW zener diode BZY88/C3v3
T1: 9V r.m.s., 300mA transformer
I1: 7V, 0·1A, 1A
R1: 22,000Ω
R2, R3, R4: 3,300Ω
R5: 3,100Ω (e.g. 3,300/47,000); see text
R6: 1,000Ω wire-wound pot meter
R7: 47,000Ω
R8: 180Ω
R9: 150Ω, 1W
R10: 390Ω; see text
R11: 3,900Ω; see text
C1: 1,000pF ceramic
C2: 1·5μF 50V metallized polycarbonate
C3: 10μF 6V electrolytic
C4: 2,500μF 12V electrolytic
C5: 25μF 12V electrolytic

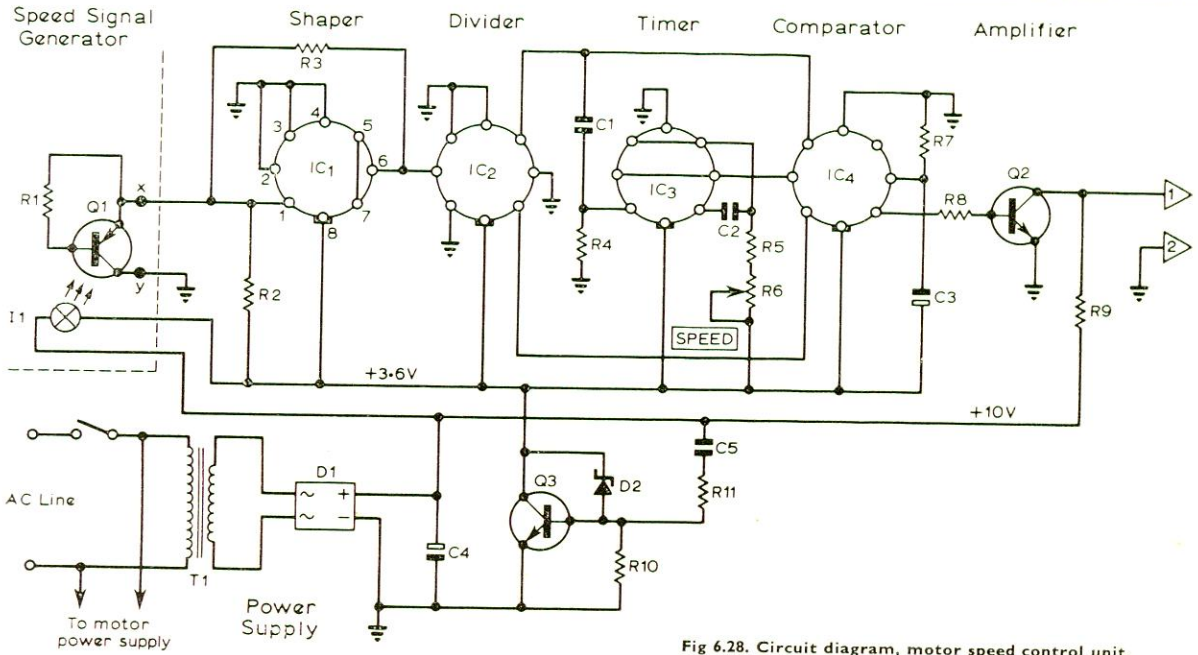


Fig 6.28. Circuit diagram, motor speed control unit.
(Parts list: opposite page)

The Shaper Divider

The shaper (IC_1) uses a dual two-input-npn gate μL914. The output level of a NOR gate is 1 if all (both) inputs are 0, and is 0 in all other cases. When only one of the two input terminals is used, the other one being held at a constant O-level (ground), the gate behaves like, and actually is, a simple grounded emitter amplifier.

The μL914 is an extremely versatile device. Besides its normal application it can be connected as a set-reset flip-flop; by adding a few external components it can be used as a one-shot or an astable multivibrator and it is also suitable for linear applications.

Here it is connected as a voltage level switch. At the output terminal (pin 6) rigid voltage steps are obtained even when the input voltage (pin 1) is varied slowly. This insures proper operation of the divider flip-flop when the motor starts.

The divider (IC_2) is a JK flip-flop μL923 which has both its set and reset terminals connected to ground and therefore operates as a frequency halver (see last line of **Table 6.6**).

The Timer

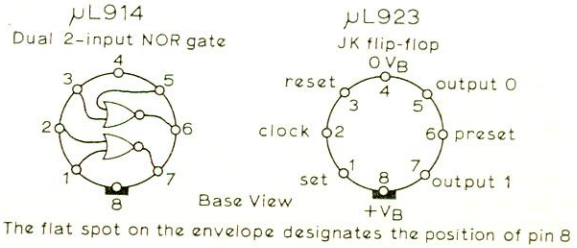
This is a μL914 connected as a one-shot multivibrator (IC_3). It is triggered by the positive spike generated by C_1 and R_4 when the voltage at pin 7 of IC_2 goes to 1. The negative spike occuring when pin 7 of IC_2 goes to 0 does not affect the timer.

The length of the output pulse of IC_3 is given approximately by the following expression:

$$T_s = 0{\cdot}8\ C_2\ (R_5 + R_6)$$

If C_2 is in microfarads and R_5 and R_6 are in kilohms, T_s is in milliseconds.

With the value shown, T_s can be varied by means of R_6 from 3·7–4·9ms, corresponding to a baud range of 54 to 41.



The flat spot on the envelope designates the position of pin 8

Fig 6.29. Integrated circuit connections.

Due to component tolerances it may be necessary to modify the value of R_5 slightly to obtain the above range.

The sensitivity of T_s to the supply voltage is such that the speed increases by about 2 bauds/V. In other words, if the speed is to remain constant within 0·1 baud, voltage fluctuations must not exceed 1·4 per cent of the mean value. This is fairly easy to achieve.

Due to the ac ripple on the supply voltage the system will show some elasticity, ie the speed will depend to some extent on the motor load. Therefore good filtering is important.

The speed also tends to increase with temperature, but probably not more than about 0·2 bauds/10°C and no special effort has been made to compensate for this effect.

The Comparator/Amplifier

The operation of the comparator has been explained in sufficient detail in the general description. R_1 and C_3 serve to get a positive situation when the circuit is turned on. At that moment a positive pulse is generated by this RC-network

and applied to the preset input terminal of IC_4 (pin 6) forcing the JK flip-flop to the 0-state, ie the state corresponding to low speed. This action lasts about 50ms, which is sufficient for the entire system to assume a stable state. If the preset input was connected directly to ground the state of IC_4, when applying power to the circuit, would be undetermined and the motor might not start unless rotated by hand until the first error detection cycle is performed. This would of course be a nuisance. When power is switched off, C_3 discharges through R_1 and the remainder of the circuit.

The output signal of IC_4 is taken from pin 7 (output 1); the complementary signal is available at pin 5 (output 0). For reliable operation the current drawn from the output terminals must not exceed 2mA.

The amplifier (Q_2) can supply 50mA of current at 2·5V and 60mA at 1V. This is sufficient to operate an electronic switch, eg a SCR or a triac, capable of handling the motor power.

The Power Supply

A shunt voltage regulating circuit is used for the 3·6V supply. It gives better results than a series regulator with the same number of components and it is inherently short-circuit protected. Moreover it has a slight negative termperature coefficient which compensates to some extent for the positive temperature coefficient of the speed regulation.

The bulb I_1 performs the function of the limiting resistor. In this way less power is wasted and due to the positive temperature coefficient of the bulb's filament the output voltage is less dependent of mains voltage fluctuations than if an ordinary resistor were used.

For mains voltage fluctuations of 10 per cent the output voltage changes by about 12mV. R_{11} and C_5 serve to reduce the ripple to virtually zero. The value of R_{10} was determined experimentally. If it is too high, the ripple is not eliminated completely and if it is too small the ripple is reversed. C_5 is for dc isolation only and its value is not critical. This little trick is effective only when the current drawn from the regulator is fairly constant. Without R_{11} and C_5 the ripple amounts to 25mV peak to peak.

If necessary, small corrections to the output voltage can be made by modifying the value of R_{10}. According to the IC manufacturer's specifications the voltage should be 3·6V±10 per cent.

Approximately 65mA is drawn from the 3·6V supply. Q3 dissipates only about 125mW and needs no cooling fin.

The Electronic Switch

1. ac/dc motors

The circuit shown in **Fig 6.30** is due to Karel Debrouwere ON5BV. It is suitable when the motor is supplied with ac. Although only one SCR is used it operates on both half-cycles of the ac supply. As compared to a triac it has the advantages of being cheaper and of presenting no problems with respect to turn-off in inductive circuits such as the one under consideration.

In case the motor is supplied with dc one may try to use the circuit of **Fig 6.30** to switch the ac input of the dc supply. Another solution may consist in switching the motor power by means of a transistor or an array of transistors of sufficient current and voltage handling capability.

2. 24Vdc motors

Some Creed 7B teleprinters are equipped with a 24V shunt motor. The speed of these motors is controlled by acting upon the field current and is inversely proportional to this current. Hence the switch must be closed when the speed is to decrease and vice versa. To this effect C_1 in **Fig 6.28** must be connected to pin 7 of IC_2 instead of to pin 5.

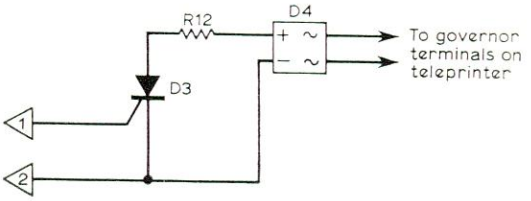


Fig 6.30. Motor electronic switch for ac/dc motors.

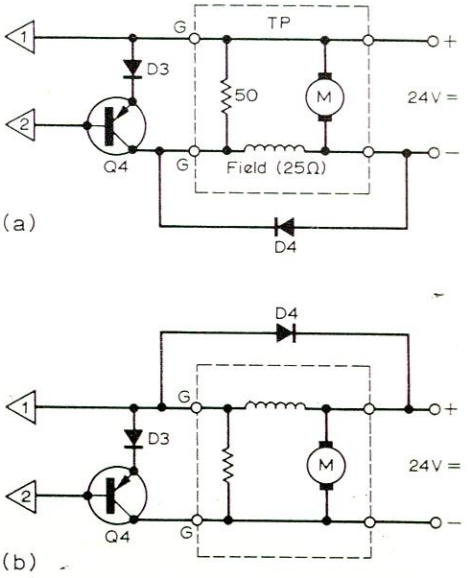


Fig 6.31. Motor electronic switch for 24V dc motors.

Fig 6.31 shows the circuit diagram of the electronic switch; an alternate solution is depicted in **Fig 6.31b**.

Q4 is a medium power pnp germanium transistor AC128 which performs its apparently heavy job of switching a power as high as 24W with remarkable ease, without needing a cooling fin. D3 ensures a proper cut-off state when the base of Q4 is at 0-level. D4 protects Q4 from being damaged by the

high flyback voltage which otherwise is developed across the field windings when the transistor goes into cut-off.

The original governor contains an additional pair of contacts which are closed at rest and open as the motor is running well. This is to make use of the maximum available torque to start the motor. It was found unnecessary to provide an electronic substitute for these contacts as the motor also starts promptly with low field current. Anyway, when the circuit is switched on, the field current is high, but it falls to the reduced value as soon as the motor starts to turn.

Description of the Mechanical System Built by ON5BV

This description is given only for information, as it is clear that there are many other possible solutions for this problem. For example, ON4VW removed the governor wheel completely and installed a metal disc in its place. A lathe and other equipment that is not always readily available to the average amateur was however needed. The three following photographs show how the system was built by ON5BV.

Fig 6.33 gives a general view of the system. The disc, 4½in in diameter, is sawn from a piece of copper-clad laminate or a similar non-transparent material. It is fastened to the governor wheel cover with two small screws. The five rectangular holes are ⅜in by ¼in. The white dot is used for stroboscopic speed adjustment.

The governor and its associated circuitry are left in place. The speed is adjusted to about 52 bauds, slightly higher than the highest speed that will normally be used. When the machine is running at 45 or 50 bauds on the electronic speed control, the governor contacts remain inoperative. Should the electronic system ever fail, the governor will enter into action and limit the speed to a safe value, protecting the teleprinter against any possible damage caused by an excessive speed. At the rear is the electronic circuitry. The printed circuit board on the illustration is not the same as described, but the first experimental one.

Fig 6.34 shows the printer seen from the left. The printed

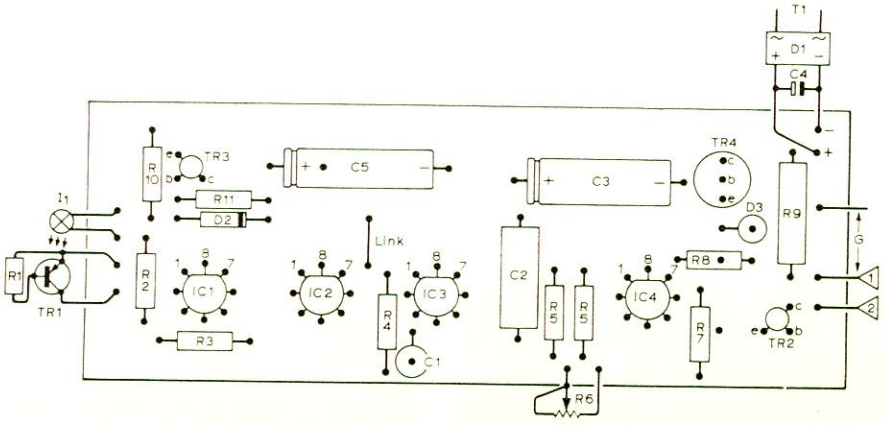
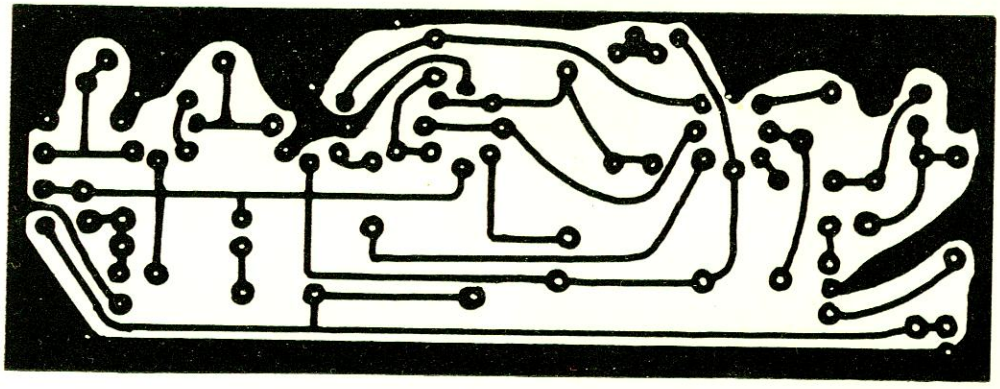


Fig 6.32. Both sides of the printed circuit board, showing component layout.



circuit board is fastened to an aluminium plate, screwed on a wooden plate that is fastened to the printer frame by means of a $\frac{1}{4}$in bolt. No holes need to be drilled in the frame. A second wooden plate, slightly larger than the rectangular hole at the rear of the frame, does the trick. The use of wood (or bakelite) provides electrical insulation between the etched circuit board and the printer body.

At the extreme left of the illustration at the rear side of the wooden plate, there is another small circuit board. This is the regulated power supply for the system. Of course, the etched circuit boards can be installed in any other convenient place above or under the printer frame.

Fig 6.35 gives a detailed view of the dial lamp and phototransistor, with the perforated disc between them. Underneath the governor wheel a small piece of etched circuit board, with just a few copper strips, is cemented to the printer frame. Its main purpose is to serve as a series of tie-points. The phototransistor, an OC71 with the black paint removed, is soldered directly on it, and positioned at the right side of the disc.

The dial lamp is connected to two other tie-points by means of two pieces of stiff wire. It would be better to mount the lamp in a socket and fix it to the printer frame. This will make its replacement much easier, should it burn out.

Both the dial lamp and transistor should be positioned in such a way that the transistor receives a light pulse each time a hole passes between them.

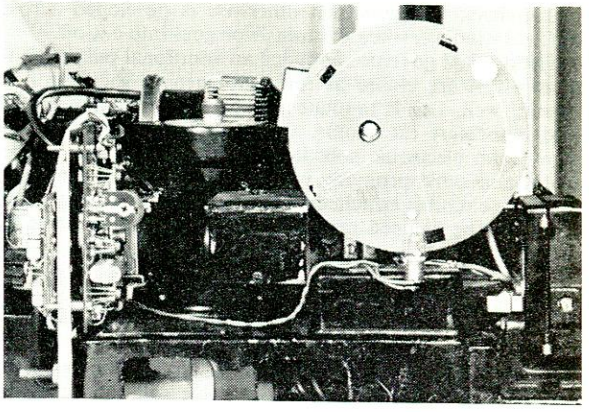


Fig 6.34. Side view of the teleprinter.

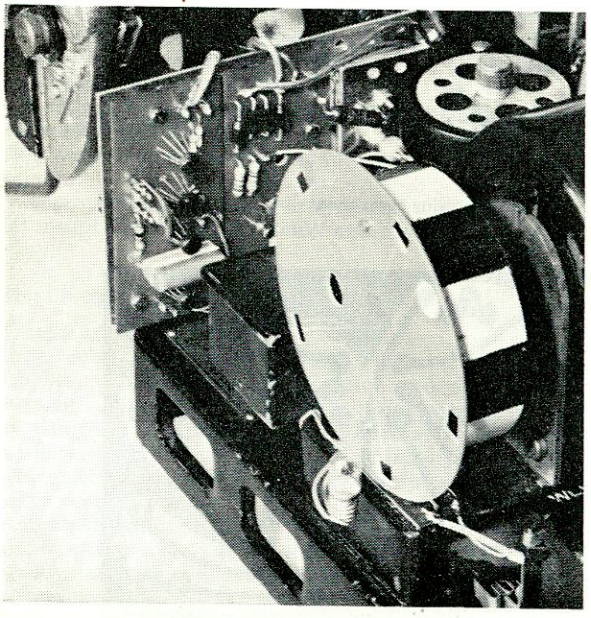


Fig 6.33. General view of the ON5BV mechanical system.

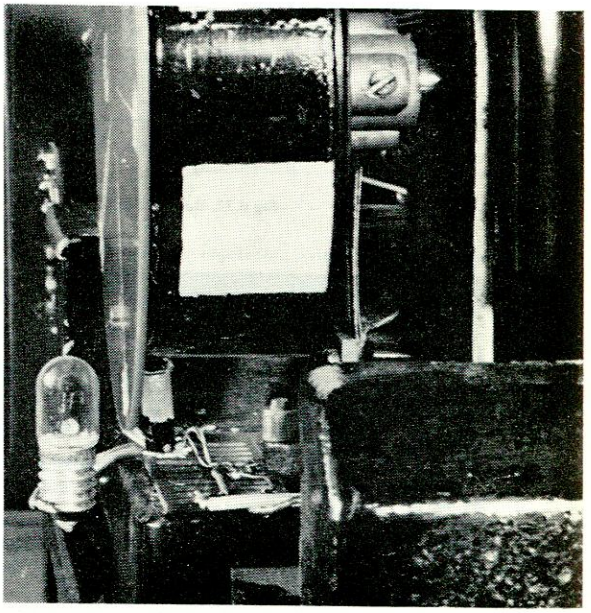


Fig 6.35. View of the dial lamp and phototransistor.

CHAPTER 7

KEYING METHODS

IN this chapter various radio-link systems will be considered which provide a practical method of transmitting the teleprinter signals. It should be borne in mind that the radio system must be suitable for use in the amateur bands, that is it must have a restricted bandwidth and the ability to work through a certain amount of interference.

To impress any form of intelligence on a radio signal is to modulate it and, therefore, consideration should be given to the relative merits of amplitude and frequency modulation.

There are many ways to transmit an rtty signal. Three of the simpler methods are:

1. On-off keying.
2. RF frequency shift keying (fsk).
3. Audio frequency shift keying (afsk).

The most efficient method would be to modulate the amplitude of a radio carrier by 100 per cent, and that will mean an "on-off" keying system. Since the preservation of the dc component (the mark-hold signal, to prevent the teleprinter from racing, and holding it in readiness for printing) is required, it could be arranged that the absence of a transmitter carrier could correspond to the space teleprinter signal and full carrier to the mark. Since the maximum frequency which need be transmitted is the fifth harmonic of the fundamental 25Hz—ie 125Hz—the sidebands will be the carrier frequency + and −125Hz, so that the overall bandwidth of the signal will be 250Hz. To restrict upper harmonics, a simple key-click filter of conventional design would be required, otherwise the high harmonic components of the square wave will cause local interference. About the only advantage such a system has to offer is that of extreme simplicity, a printer being connected in place of the usual Morse key. Providing no unsuitable keying relays are used, the transmitter requires no modification.

From a practical communication point of view, this system is unworkable over any distance due to interference. Any interfering signal (including atmospherics) appearing during the space character when the transmitter is not radiating, will appear as a mark at the receiving end with the result that printing will be completely upset. A reversal of the keying so that "transmitter off" corresponds to mark will be even worse, any interference arising during the comparatively long breaks between letters when hand sending will start the receiver printer, thereby resulting in complete loss of intelligibility. It may take several characters before the teleprinters again come into synchronism. Suppose, for example, the letter A is transmitted. The teleprinter will send a start signal, two marks and three spaces in sequence, and then one and a half bauds stop signal. If, due to a sudden burst of interference, the start signal was not received, the receiving teleprinter would remain at rest until the first space, element 3, was received. This would be interpreted as the start signal and the mechanism would still be revolving on that character when, in fact, the next character was coming over the air. This is why the stop signal has an odd half baud in its length. If the complete character with its synchronizing signals were an exact number of bauds in duration, one dropped start signal could throw the teleprinters out of synchronism until such time as there was a pause in transmission. Even as it stands, one dropped start signal can throw the teleprinters out of synchronism for several characters, depending on their make-up, and this is the great weakness of the start-stop system.

If modulating the amplitude of the wave is unsuitable then the frequency must be modulated instead. This means that the carrier is going to be frequency modulated by the 25Hz (maximum) square wave output of the teleprinter. In normal frequency modulation, the amount of carrier shift depends upon the amplitude of the modulating signal, while the rate of frequency shift depends upon the frequency of the modulation. In this case the amplitude of the modulation is unchanging and can be any figure we like to choose. The frequency of the modulation will be the reversal voltages obtained from the transmitting printer contacts, this causing the carrier to "jump" suddenly from one frequency to another—the amount of "jump" being known as the "frequency shift". Because this is a telegraphy system, it is often called "frequency shift keying", but although it bears this name, and mechanical means may be used to bring it about, it must be remembered that the result is just ordinary frequency modulation of the carrier—the same rules applying in calculating the bandwidth occupied by the signal just as though we were considering the transmission of, for example, speech or music by this method.

In order to calculate a typical bandwidth occupied by an fsk teleprinter radio signal, we must first decide the amount of shift to be employed. This is generally in the order of 800Hz on the hf bands, and this figure will be used as a basis for the calculations. Since we are dealing with frequency modulation which is varying by 800Hz from one extreme to the other, we can imagine that there is a central carrier frequency which is being shifted ±400Hz. Admittedly, this carrier is never transmitted in reality, but looking at it from this point of view makes it rather easier to understand. If we imagine a central carrier on 3,700kHz, being frequency modulated by a teleprinter signal, then the frequency corresponding to mark might be 3,700·4kHz, while that corresponding to space would be 3,699·6kHz, and the signal as a whole must occupy a bandwidth equal to the total shift, ie 800Hz.

It can be quickly seen that the bandwidth must at least be the total shift produced by the modulation, but this is not quite all. During transition from mark to space the carrier is rapidly changing from one frequency to another and additional sidebands must therefore be generated.

It may be shown that the rapidity with which this change

takes place is governed by the number of harmonics of the fundamental 25Hz signal which we are prepared to pass from the transmit to the receive position—and it was also concluded that transmission of the fifth harmonic was sufficient, ie a frequency of 125Hz. For our "modulation frequency" we have, therefore, 25Hz, 75Hz and 125Hz—all frequencies being maximum figures—and we must now consider the overall bandwidth required to transmit this composite signal by fm.

As all fm enthusiasts will know, the detailed calculation of the bandwidth of these signals is very involved, but for our purpose a very simple treatment will suffice. Assuming that modulation is 100 per cent (as it must be with telegraphy) the criterion of an fm signal is the ratio between frequency deviation and modulating frequency. This figure is known as the modulation index. Using a standard shift of 800Hz (which will be 400Hz relative to the imaginary central carrier), our signal will have three modulation indices: 400/25 = 16, 400/75 = 5·3 and 400/125 = 3·2.

Reference to any frequency modulation textbook will reveal a diagram or table which indicates the bandwidth, or number of sidebands, appropriate to various modulation indices. It may be summarized by saying that when the modulation index is 16, sidebands up to the 25th will be significant, when the index is 5·3 then nine sidebands will be significant, and when the index is 3·2, five sidebands will be present. At first glance this looks a pretty grim picture until calculation is carried further. Twenty-five sidebands of 25Hz only equals 625Hz, nine sidebands of 75Hz equals 675Hz, and five sidebands of 125Hz equals 625Hz. Further, the 75Hz and 125Hz components of the signal are only $\frac{1}{3}$ and $\frac{1}{5}$ the amplitude of the main transmission, being somewhat attenuated at the start. It appears, therefore, from the above that sidebands will not extend more than 675Hz either side of the imaginary central carrier, making a total bandwidth of 1,350Hz—but, in fact, this is being rather generous and in practice satisfactory operation can be obtained by limiting the sidebands to ±500Hz, making a 1kHz bandwidth overall. Although it might appear from the foregoing that all the harmonics could be transmitted, since the lower modulation indices that result with the higher frequencies mean lower numbers of sidebands, this is not so. Consider the 100th harmonic—2,500Hz. Although the modulation index will be low, even the smallest amount of sideband energy radiated will be in multiples of 2,500Hz either side of the central carrier, and the bandwidth will be excessive.

Since these sidebands only exist at the moment of transition from mark to space or vice versa, they will sound like key clicks, being very objectionable, particularly to local stations. Some sort of low-pass filter, therefore, attenuating all frequencies above 125Hz, should be employed between teleprinter and modulator. It may, in practice, be found that clicks do not result even if this filter is not used—this may be due to several different reasons, one of the most likely being that since frequency modulation is normally produced at the oscillator, the subsequent passage through the doubler and/or amplifier tuned circuits will attenuate the upper harmonics before they can do any harm. It is, however, far better to use a filter in the first case, these types of key clicks being most objectionable when they occur.

In the above example the shift was quoted as being ±400Hz, ie 800Hz in all. This figure has largely become standard on the hf bands, although there is no essential reason why the amateur should use it, except it is most desirable that a definite standard is laid down. Reduction of shift will reduce the bandwidth occupied and this would, of course, be beneficial on the amateur bands, particularly as it would enable teleprinter signals to be copied through the simple type of crystal filter found on some older receivers. There is a figure for minimum shift which can be employed, but this is in the order of 60Hz, being bound up with the operating speeds in bands, and will obviously not concern the amateur. If amateurs were to use, say, 400Hz shift, better working through interference would be possible, although increased stability on the part of transmitters and receivers is, of course, necessary. It seems unlikely that advanced amateur stations use unstable equipment these days, therefore the use of reduced frequency shift should be seriously considered.

The system will obviously discriminate against many types of interference. Since it is essentially fm, discriminator circuits preceded by amplitude limiters may be used at the receiving end, fading becoming of no importance (unless the signal fades completely when any communication system must fail). Since both mark and space signals are transmitted, interference cannot occur during an "off" period as with amplitude modulation. The amount of interference that can be tolerated is really a receiver problem and will be dealt with under that section, it being clear at this point that the system is likely to show up well from this angle.

Selective fading can be troublesome at times, when perhaps either the mark or space signals will disappear. Suitable receiving circuits can cope with this to a limited extent but absence of one signal leaves an open path for interference to cause trouble.

The system caters adequately for the preservation of the dc component and a mark signal can go on indefinitely. During this time the receiver is protected against random bursts of interference and will only release when a space signal is received.

Distortion of the signal may appear in any radio system, though this is not likely to trouble the amateur. It may arise when reflected signals are received a fraction of a second later than those arriving by a shorter path, or, under certain circumstances, when signals are received both via the long and short paths round the world. With amplitude modulation, the effect would be the prolongation of the original signal by the later reflected one. With the fsk system this is not so troublesome since any reflected signal is likely to be weaker than the direct one. The receiving circuit is usually arranged to follow the strongest signal so that if the direct signal changes from, say, mark to space, and there is still present a much reduced mark signal due to reflection, the receiving circuit should move directly to the space condition, responding to the full strength space signal rather than to the weaker mark. Of course, under very adverse conditions, strong multiple reflections may occur and then printing is likely to be faulty. We all know conditions where cw signals flutter rapidly, or sound like a T7 note—well, rtty is unlikely to work then! Sometimes the mark and space signals, being on slightly different frequencies, will follow different paths, thereby causing their relative position to be misplaced on arrival at the receiving end—in other words, distortion occurs. Nothing much can be done about this, though by means of special repeaters the signal may be cleaned up before being passed to the printer.

There remains one other mode of transmission to consider,

and this is really a compromise of a.m. and fm. If a vhf link is required then the simple a.m. system will be prone to interference, unless it is only radiated over a mile or two, while stability requirements make the fm system difficult to work. The answer is to modulate the carrier in the normal a.m. manner with two audio tones, one corresponding to mark and the other to space. This has all the simplicity of the normal a.m. system, while imparting a number of the fm advantages. To achieve this, the teleprinter is arranged to shift the frequency of a small audio oscillator, the output from this oscillator being amplitude modulated to the vhf carrier in the normal manner. It might be thought that this system would find application on the hf band as well, and it can indeed do so. Its main drawback is its inefficiency. A complete audio modulator would be needed resulting in a low overall efficiency at the transmitting end. At the receiving end it is well known that the output of the modulation contained in a carrier cannot be as great as that of the carrier itself, therefore a much larger signal will be needed at the receiving end in order to produce the same power output compared with straightforward fsk.

The combined a.m./fm system (known as "amplitude modulated fsk", or "afsk") can, however, achieve one result that the fsk system cannot—and that is to handle several different teleprinter signals simultaneously. Two or more printers can be used at the transmitting end, each working into different audio oscillators and producing different pairs of tones. These tones can all be amplitude modulated to the carrier, being separated by audio filters and passed to different printers at the receiving end. This enables multi-channel information to be conveyed on one carrier. A much modified form of this system can be applied to the hf bands, although multi-channel systems have little application in the amateur field.

The block diagram shown in **Fig 7.1** is of an fsk transmitting set-up as applied to a cw/a.m. transmitter. The fsk keyer would be arranged to change the frequency of the vfo in sympathy with the teleprinter keyboard signals.

To obtain a frequency shift, the inductance or capacitance of the tuned circuit must be changed. This can be done by a simple keyed method as shown in **Fig 7.2**. On space, C is shunted across the vfo tuned circuit, thus lowering the frequency. This basic method and its variants using relays is not very satisfactory due to the capacitance of the keying contacts and the leads to them, and to the production of undesired transients. The keying is usually carried out electronically.

Fig 7.3 shows a simple keying circuit which gives good results and is one of the more popular methods. The diode D may be either a semiconductor or a thermionic type, although the former is more common. The circuit functions by switching the capacitor C across the vfo tuned circuit. At mark, the diode anode is negative and the diode does not conduct, so C is not in circuit. On space, the anode is positive, the diode conducts, shunting C across the tuned circuit and so lowers the resonant frequency. The amount of shift may be adjusted by varying the switched capacitor C or by adjusting the amount of bias voltage applied to the diode. For best results, the bias voltage should be stabilized, as any variation will effect the shift.

This circuit will also work with a single current system, as the diode will only conduct on the positive pulses, and not during the no-current times.

A variation on this method would be to use one of the

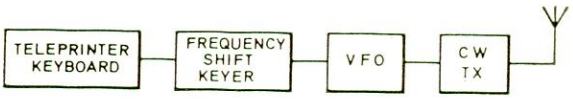


Fig 7.1. Block diagram of a simple rtty transmitter.

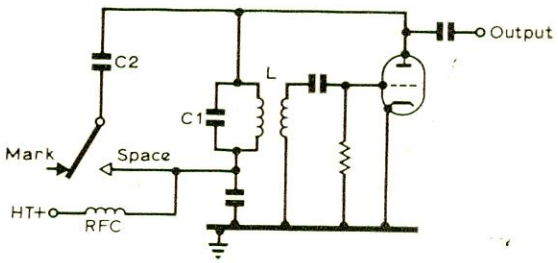


Fig 7.2. Basic method of frequency shift keying an oscillator.

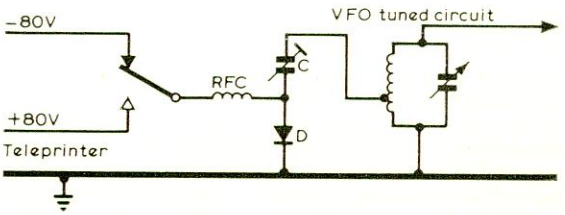


Fig 7.3. Elementary method of diode frequency shift keying.

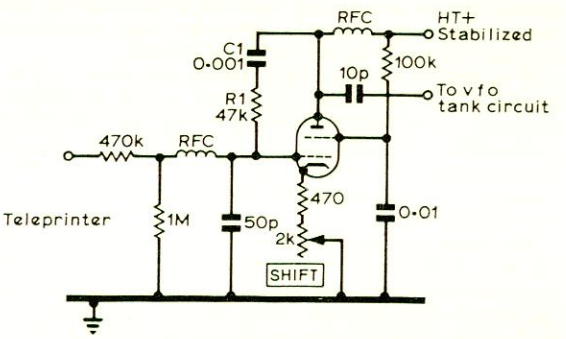


Fig 7.4. Reactance valve keyer circuit diagram.

variable capacity diodes. These devices have a self capacity which changes with the applied dc voltage and they provide a simple method of achieving fsk with the minimum number of components.

The above two methods are known as impedance keying. An alternative way of changing the frequency of an oscillator is to use a reactance modulator. In this circuit arrangement a second valve is connected in a phase shift network so that it behaves either as a capacitor or an inductor, and it is then connected across the oscillator tank circuit, **Fig 7.4**. The value of the "capacity" or "inductance" is dependent upon the current drawn by the reactance valve, so that if its grid voltage is changed the C or L changes accordingly. The dc signals from the teleprinter are applied to the grid, and are reproduced as reactance changes across the oscillator tank circuit, so producing fsk. The grid is connected to the anode via a phase change network C_1R_1 so the anode current leads the anode voltage by 90 degrees. The anode and cathode of the pentode now form effectively the two plates of a capacitor. The valve now behaves as a variable reactance in parallel with the tuned circuit, and the variations of grid voltage will change the oscillator frequency.

It must be remembered that although the deliberate voltage changes are applied to the grid, a change of any of the electrode voltages will produce a change in anode current and a consequent change of reactance. A stabilized ht supply may, therefore, be considered essential with this circuit.

The amount of frequency shift produced may be altered in two ways. Either the value of the dc from the printer may be altered, or, what is often easier, the value of the fixed bias applied to the reactance valve may be altered instead. Since the changing voltage from the teleprinter is applied on top of the steady bias, it follows that the amount of frequency shift produced will be greater or smaller according to whether the changing voltage is a large or small percentage of the total bias. The shift control, therefore, can be a variable resistor in the cathode of the reactance valve.

The systems so far discussed suffer from one disadvantage, that is if the operating frequency of the oscillator is changed, so also is the amount of frequency shift. Since, no matter which circuit is used, the frequency shift is produced by varying capacity or inductance relative to the oscillator tank constants, it follows that if these constants are altered so is the amount of shift. This would not be troublesome when moving frequency on one band, but if the oscillator tank components are changed then the amount of frequency shift will require resetting. The majority of amateur radio transmitters do not change oscillator tank constants when changing from one band to another, but either multiply the oscillator frequency or use mixing techniques.

If multipliers are used the problem still exists, but in a modified form. If an fsk signal with a shift of 800Hz is generated on 3·5MHz and this is doubled to 7·0MHz, the shift will also be doubled to 1,600Hz and if the frequency is again doubled to 14·0MHz, the shift will become 3,200Hz. Consequently, resetting of the shift will be required whenever the band is changed.

The mixing technique overcomes all the mentioned difficulties by associating the fsk device not directly with the vfo, but with another oscillator operating on a completely different and usually fixed frequency which has its output mixed with that of the vfo to provide the final frequency, **Fig 7.5**. For example the fsk generator might operate on 5MHz. This

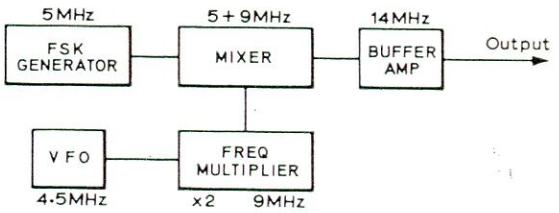


Fig 7.5. Block diagram of a mixer exciter.

could be mixed with a vfo on 1·2 to 1·5MHz to give an output in the 80m band, and with a vfo on 2 to 2·15MHz for output on the 40m band, etc. The amount of shift is unchanged and independent of the final frequency.

The alternative to producing fsk in an oscillator is to use an ssb transmitter or the exciter portion of one. If a constant tone is fed into the modulator of an ssb exciter, a definite carrier frequency is produced, and if the audio tone is changed, then the carrier frequency is shifted by exactly the same amount. Consequently if two audio tones, one corresponding to mark and the other to space, separated from each other by 850Hz, are fed into the ssb exciter, the output is fsk by 850Hz, no matter what the actual radio frequency may be. It does not matter what the frequency of the audio tones are (providing they are within the passband of the audio section of the exciter), so long as they differ by the required amount of frequency shift.

However, if an ssb transceiver is used it is more usual to choose two tones which can be received without having to adjust the vfo control at all and so avoid any possible "leap-frogging" up or down the band as each station retunes the other during receive intervals. If an ssb transceiver is operated on upper sideband and modulated with tones of 1,650Hz for space and 2,500Hz for mark, the transmitted space carrier would be 850Hz below the mark carrier, in conformance with standard practice. In the receive mode, 1,650Hz space and 2,500Hz mark tones are received from a zero-beat rtty station.

This popular method is used by many stations because it takes advantage of transceive operation by tracking transmitted space and mark tones. System alignment is straightforward, and no transceiver modifications are required. Although this method is attractive, good design practices must be observed to ensure a high quality fsk signal.

The transmission of two carriers simultaneously is not permitted, and so the ssb exciter must suppress the unwanted sideband and the primary carrier by at least 30dB, and the exciter must operate with the primary carrier completely balanced out. Any noise accompanying the audio tones will be transmitted, resulting in a waste of power and causing adjacent channel interference. The signal-to-noise ratio of the audio tone signal that modulates the exciter should be at least 35dB to ensure against transmitting appreciable noise.

The audio tone waveforms should be high quality sinusoids having less than 5 per cent distortion. A nonsinusoidal waveform contains harmonic components of the fundamental frequency. For example if a nonsinusoidal 500Hz tone modulated the transceiver, several undesirable secondary carriers would be transmitted, which could have frequencies displaced from the primary carrier by 500, 1,000, 1,500, 2,000 and 2,500Hz.

The crystal or mechanical filter bandpass characteristics

in filter type ssb generators would attenuate any secondary carrier displaced from the primary carrier frequency by more than 2·7kHz. Multiple secondary carrier transmission by amateurs is not permitted, so a high quality sinusoidal audio modulation waveform is required. The mark and space tone frequencies can be selected to compensate for deviations from a pure sinusoidal audio waveform. **Fig 7.6** shows a typical crystal filter bandpass characteristic of an amateur ssb transceiver. Shown is the position of the pimary carrier fp, relative to the filter passband. With the primary carrier on the skirt of the filter selectivity curve, the crystal filter attenuates the primary carrier and provides more carrier suppression than can be obtained in the balanced modulator alone. The tone frequencies are chosen so that the associated secondary carriers will be near the high-frequency cut-off point, but within the flat response region.

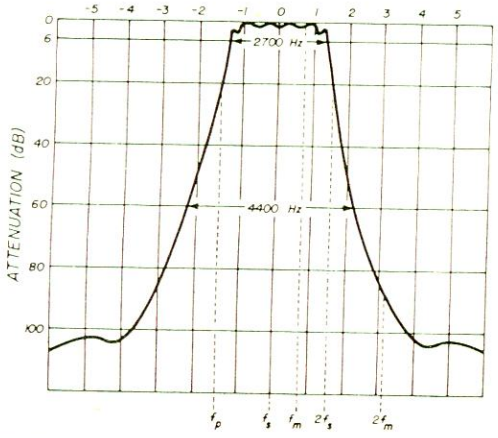


Fig 7.6. Typical bandpass characteristic for a filter-type ssb (usb) exciter in the rtty mode. Primary carrier is represented by fp; secondary carriers of 1,650Hz (space) and 2,500Hz (mark) are shown by fs and fm.

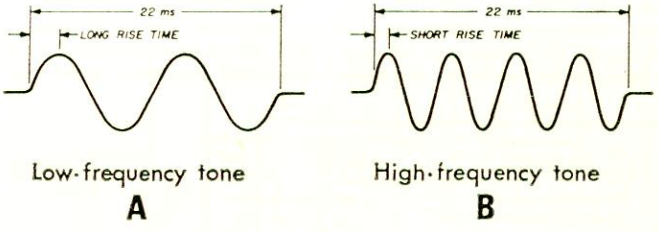
Fig 7.6 shows the relative position of the primary carrier fp, and the secondary carriers fs and fm for space and mark tones of 1,650 and 2,500Hz. These fundamental space and mark frequencies lie within the passband and are not attenuated. However, the harmonics of the fundamental tones lie outside the passband and will be attenuated. Consequently the high-frequency filter selectivity skirt attenuates the secondary carriers produced by any existing harmonic content (distortion) of the audio tones.

Fig 7.6 also shows that by selectivity 1,650Hz space and 2,500Hz mark frequencies, the second harmonic space and mark secondary carriers 2fs and 2fm, are attenuated by 20 and 85dB respectively. Although this technique can be used to compensate partially for audio tones having some harmonic content, every attempt should be made to generate pure sinusoidal modulation tone waveforms.

There is a second reason for choosing tone frequencies near the high frequency skirt of the filter selectivity curve. High tone frequencies are desirable so that more cycles of the tone can be contained within the mark and space intervals. High tone frequencies allow the use of more selective tone filters in the receiving converter. Also, a high tone frequency represents a shorter rise time or a better leading edge of the space or mark signal, as shown in **Fig 7.7.**

Perhaps the most important consideration is the requirement for generating a continuous-phase a fsk signal. The need for phase continuity is best emphasized by considering the effects of an afsk modulation waveform having phase discontinuities. **Fig 7.8** illustrates the difference between the two waveforms. The waveform with phase discontinuity results in (*a*) amplitude modulation of the fsk signal, and (*b*) impulse noise being generated and transmitted.

The sharp switch transients have many frequency components, resulting in the transmission of a 3kHz wide noise spectrum. The transmitted noise bandwidth is limited by the filter frequency response. Because the duty cycle of the switching transient is low, the transmitted noise power is much less than the secondary carrier power. However, this impulse noise does cause adjacent channel interference.

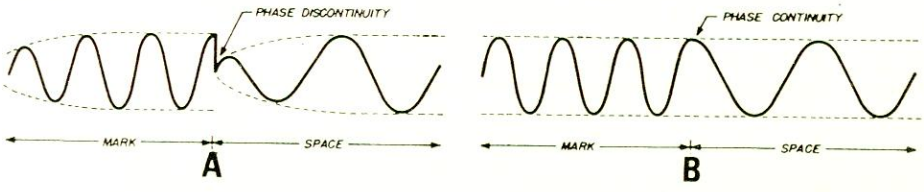


ABOVE:

Fig 7.7. Comparison of low- and high-frequency afsk tones. Signal at B allows use of more selective filters and provides a better leading edge of space or mark signal.

BELOW:

Fig 7.8. Comparison of mark-to-space waveform transistors. Phase continuity avoids adjacent-channel interference because impulse noise is greatly reduced.



Earlier in this chapter, mention was made of the system known as amplitude modulated frequency shift keying. For the reasons so far considered, this method is not used on the hf bands, but is very popular on vhf because of the simplicity of applying such a system to an existing vhf a.m. transmitter, and because of possible problems with stability when frequency shift keying a crystal controlled oscillator which precedes several multiplier stages. The problems considered so far still apply with this method, but as the spacing between stations is greater at vhf, they are not so acute.

Fig 7.9 shows the modifications to a *Heathkit* VF1U vfo to enable its use for fsk. Room can be found for the 6AL5/EB91 valve holder at the back of the chassis, and the 1MΩ potentiometer can be fitted at the top right-hand corner of the panel without upsetting the appearance of the unit. The teleprinter transmitting contacts are connected across X and should be made so that the higher of the two tones produced occurs when the contacts are in the open or space position. The degree of frequency shift can be controlled by the 1MΩ potentiometer.

A variation on **Fig 7.3** is shown in **Fig 7.10** and this circuit may be taken as a universal unit that will work with almost all oscillators. The assembly should be mounted right next to the oscillator and wired up with a short, stout lead to eliminate any tendency to drift. The connection to the oscillator may be to the main tuning capacitor, the tank coil, or to the cathode of valve oscillator which is "hot" to rf. The switch S1 is used to select "wide-off-narrow" shift, and may be placed anywhere that is convenient, such as on the teleprinter keyboard or the station control panel. The circuit may be used with TUs having keyer outputs such as the ST5 or TTL/2, described in chapter 5. If this type of keyer output is not available, almost any voltage will operate it from 1·5V upwards, but precautions should be taken so as not to exceed the diode ratings if much higher voltages are used. By placing a key across the keyer contacts, cw identification may be transmitted. If IN270 diodes are not available other types may be tried but they should be germanium as the low forward voltage drop aids maximum shift.

The circuit of a very simple afsk unit for vhf is shown in **Fig 7.11**. Any npn transistor will work but one with low gain works best to keep the output down. When using a 2N167 transistor the centre tap of the toroid can be used instead of 10 turns of wire around the toroid for the feedback to the transistor. It will be found that the greater the turns on the feedback winding, the greater the output.

Tuning the 2,975Hz tone with the toroid and C1 may be accomplished by removing turns from the toroid. Tuning the 2,125Hz tone C2 only should be adjusted.

Keying is accomplished by switching C2 in and out, and may be done by diode switching.

An afsk Keyer

Although an afsk keyer can be built with a single oscillator and a capacitor placed across its turned circuit to shift the frequency, more versatility can be obtained by using two separate continuously-running ocillators whose outputs are "gated" by the opening and closing of the keyboard.

Two advantages of separate oscillators (one for mark and one for space) are:

1. The frequency of each oscillator can be adjusted independently of the other, and
2. The levels of mark and space tones can be independently adjusted.

The oscillators use the familiar Hartley circuit consisting of an 88mH toroid shunted by the proper amount of capacitance to give the required 2,125 and 2,975Hz resonant frequency, **Fig 7.12**. The values shown for C3 and C4 are the approximate values required. The exact values should be determined by measuring the output frequency and adjusting the capacitors until the frequency is proper. The capacitors can be "varied" by shunting small mica capacitors across C3 and C4 or by using trimmers.

The oscillator transistors are 2N3819's. These are N-channel junction field effect transistors. The resistors R1 and R2 and the capacitors C1, C2 and C5 are for decoupling. R1 and R2 can be used to measure the drain current on the transistors. It should be from 4–8mA.

The keyboard is connected into a "loop" composed of R6, R7 and R8; the loop is fed from 130V or higher. R6 is adjusted to give a loop current of 60mA. (Actually, R6 is not really necessary and the loop current does not have to be set to 60mA unless a selector is also put into the loop. The selector is undesirable for reasons described later, but "force of habit" or good telegraph practice indicate that 60mA is desirable.)

Assuming that R6 is present and it has been adjusted to give 60mA loop current, during marking condition from the keyboard (contacts closed and 60mA flowing in the loop)

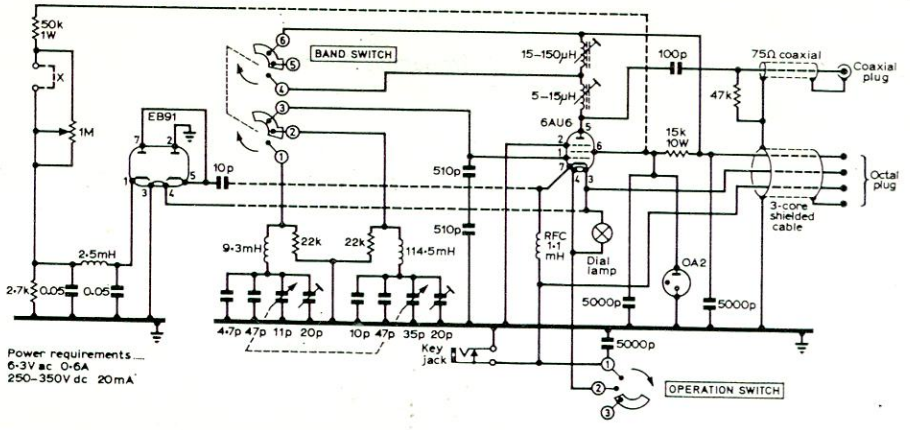


Fig 7.9. Modifications to a Heathkit VF1U vfo for use for fsk.

the potential at point "A" is approximately +48V; during the spacing conditions (no loop current), the potential at point "A" is approximately 0V. This variable potential is coupled into the diodes D1 and D2 through delay network composed of R9, C6 and R10. The varying potential at point "A" causes one or the other of the diodes to conduct. For example, during a mark the potential at point "A" is +48V; this voltage causes diode D2 to conduct or gate the output from the mark oscillator into the output amplifier Q3. The output from the space oscillator will be blocked from Q3 because D1 is reverse biased.

During a space, the voltage at point "A" is approximately 0V, causing D1 to conduct and D2 to open. Therefore, during a space the output from the space oscillator as connected to Q3 via D1 and the output from the mark oscillator is blocked from Q3 by non-conducting diode D2.

R4 and R5 control, independently, the levels from the two oscillators while R11 controls both levels simultaneously.

The network composed of R12, L3 and C7 is essentially a "simple-minded" bandpass filter. The output stage is a common-source amplifier transformer coupled to the transmitter audio input circuit.

Capacitors C1 and C2 can be any value greater than 1μF. C5 should be as large as possible.

It was found that the frequency of the oscillators changed less than 1Hz when the supply voltage was varied from 18V to 26V. With stability that good, no regulation is required.

The diodes should be silicon junction diodes. This is desirable in order to get a good forward to backward resistance ratio with the magnitudes of oscillator and switching voltages available.

The switching delay network composed of R9, C6 and R10 can be changed if more diode current is required or if the time constant is considered too long. In the circuit shown,

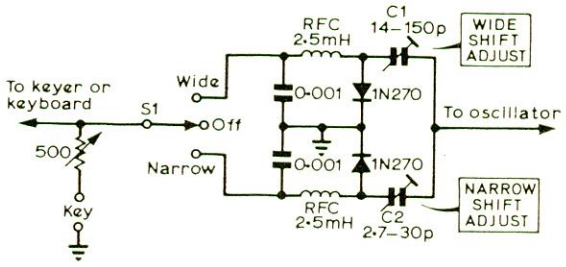


Fig 7.10. Circuit diagram of the most popular diode frequency shift keyer.

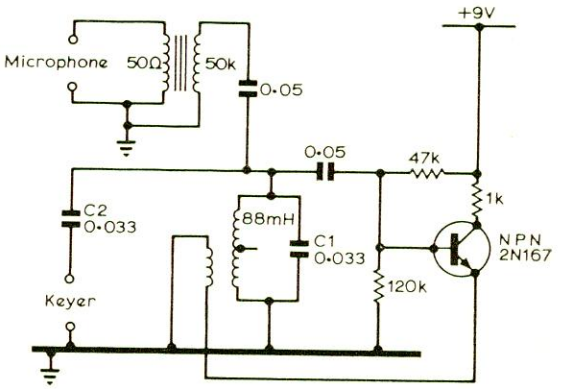


Fig 7.11. Circuit diagram of a basic afsk oscillator.

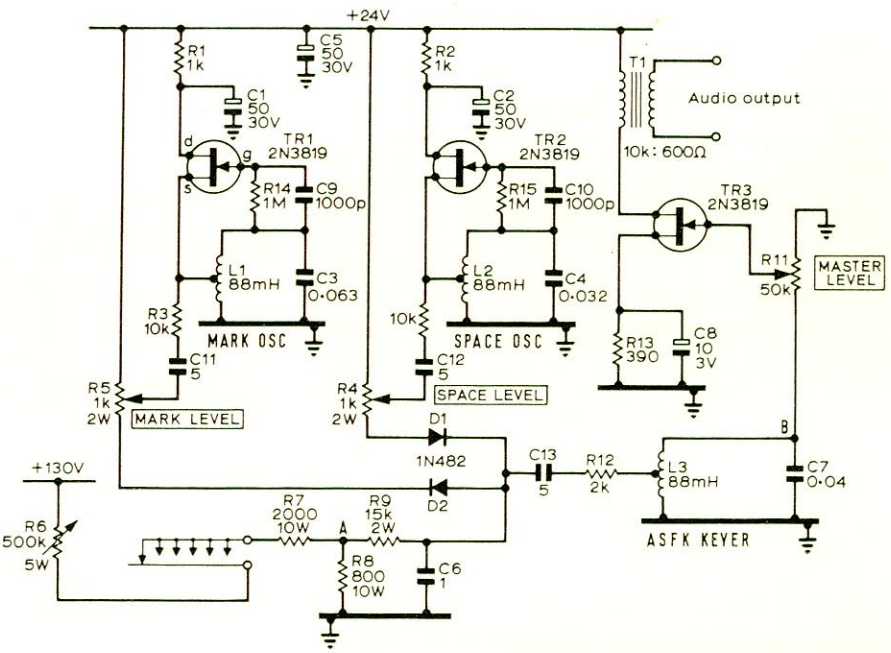


Fig 7.12. Circuit diagram of a twin oscillator afs keyer. A 2.2k resistor, R10, should be shown connected between the junction of R9, C6 and the junction of D1, D2, C13.

the total switching time is approximately 8Hz at 2,125Hz or about 4ms. If the 1N482 is used, the network is optimum.

The "filter" network composed of R12, L3, C7 and R11 is tuned to resonate at approximately 2,550Hz. The best turning procedure is to adjust the size of C7 so that the mark and space tones appear at the output at equal levels when R4 and R5 are wide open. The Q of the L3-C7 circuit is kept low by using the 50kΩ potentiometer (R11) and the coupling resistor R12. This filter serves several purposes: (1) it cleans up any harmonics from the oscillators, (2) it removes the harmonics generated by the diodes during the switching interval when the diodes are partially-conducting, and (3) it helps remove the low frequency transients caused by the dc used to switch the diodes.

The 24V power supply should be "stiff" so that the loop keying does not affect the keyer in a manner other than the desired one.

When wiring the loop, it is advisable to separate the wiring in the loop circuit from the remainder of the unit. This is desirable because "spikes" may be present in the loop due to bouncing contacts etc, and these "spikes" could get into the output and into the transmitter.

One note of caution: as is the usual case, too many selector magnets in the loop will cause spacing bias on the transmitted signal. The spacing bias can be reduced by decreasing the size of R8. The best way to eliminate the bias is to prevent it, ie don't put selector magnets in the keyboard loop!

AUDIO FREQUENCY SHIFT OSCILLATOR FOR RTTY

This oscillator, employing only four transistors, is of a fairly simple design and can be used either with a ssb rig or a vhf transmitter. The function of the circuit is to produce a single tone audio oscillation which can be remotely switched between two set frequencies. This is achieved by using an astable multivibrator, producing an approximately square wave output, of fundamental frequency either 2,125Hz (mark) or 2,975Hz (space). A low-pass Tchebyshev filter follows the multivibrator to produce a sine wave output. Should the tones be required to pass through a high selectivity ssb filter, then two other frequencies, 850Hz apart, will have to be used, eg 1,275Hz and 2,125Hz.

Multivibrator

Fig 7.13 shows an elementary multivibrator circuit together with the voltage waveforms at the collectors and bases of the transistors. The design formulae for this circuit are:

$$T = 2{\cdot}3\ C\ R_b \log\left(\frac{2V_{cc} - V_{ce(sat)} - V_{be}}{V_{cc} - V_{be}}\right) \quad \ldots 1$$

$$R_b < H_{fe}\ R_L \quad \ldots (2)$$

where:

V_{be} is the base-emitter voltage of a conducting transistor, typically 0·5V for silicon.

V_{ce} is the collector-emitter voltage of a saturated transistor ie switched hard on. Typically 0·1V.

T is the half-period of the oscillation and is given in seconds when R_b is in ohms and C is in farads.

H_{fe} is the large signal (switching) gain of a transistor. The limitations of this circuit are:

(*a*) R_L needs to be significantly less than R_b, so that the output voltage rise time is small compared with the half-period T.

(*b*) As can be seen from the base emitter waveform in **Fig 7.13,** the base emitter junction of each transistor becomes heavily reverse biased (almost equal in magnitude to the supply voltage) on each cycle. With modern silicon transistors this could at worst result in permanent damage but more probably would cause the circuit to oscillate at a frequency higher than that designed. The solution is to add a diode in series with each base, see **Fig 7.14**, D_1 and D_2. This however, means that there are two junction voltages to be accounted for and the terms V_{be} in equation (1) should be taken as approximately 1V.

If a 12V supply (V_{cc}) is used then equation (1) becomes:

$$T = 2{\cdot}3\ C\ R_b \log\left(\frac{24 - 0{\cdot}1 - 1{\cdot}0}{12 - 1{\cdot}0}\right)$$

ie $T = 0{\cdot}733C\ R_b$

Having established the basic oscillator circuit and design formulae the next stage is to choose a suitable collector load, R_L. In doing so, the circuit impedances of the low-pass filter must be considered, as these will set a maximum limit for R_L. In fact, this becomes a mathematical cut and try technique to obtain optimum convenience of components without affecting the filter performance. In the present design the filter has input and output impedances of 10kΩ which means that the collector loads can be no more than a few kilo-ohm. If the transistors are considered to have a switching gain of at least 20, thus allowing almost any transistor to be used, equation (2) will set a maximum value of R_b to approximately 40kΩ. For the frequencies 2,125Hz and 2,975-Hz the final values of R_L, R_b and C are:

	2,125	**2,975**
R_L	2·2kΩ	2·2kΩ
R_b	32kΩ	23kΩ
C	0·01μF	0·01μF

The techniques used to change the frequency from 2,125Hz to 2,975Hz is to short out part of R_b.

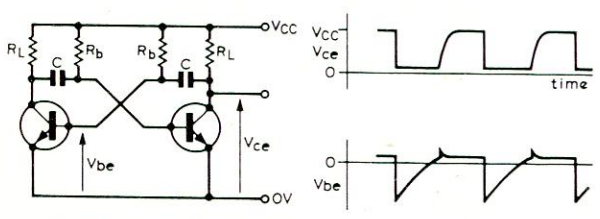


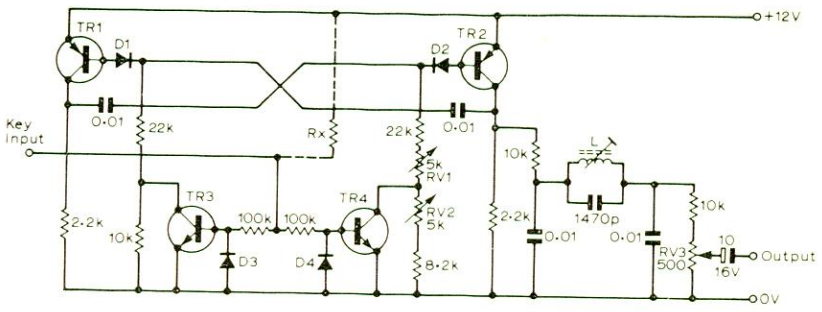
Fig 7.13. Circuit diagram of an elementary multivibrator.

Filter

In **Fig 7.15** the circuit and response of the low-pass filter is shown, the design limits of which were chosen to be:

Passband ripple	1dB
1dB cut-off frequency	3·0kHz
Notch frequency	6·375kHz
Source impedance	10kohm
Load impedance	10kohm

Fig 7.14. Circuit diagram of the afs keyer.
TR1, TR2: BCY71/2 or similar.
TR3, TR4: BC107, 2N2926 or similar.
D1-4: 1N914.
L: 425mH.



The significance of the notch at 6·375kHz is that it will eliminate the third harmonic of the mark frequency.

Using formulae and tables from Skwirzynski [1], the following values were obtained:

$C_1 = C_3 = 0{\cdot}01\mu F$; $C_2 = 1{,}410pF$; $L = 444mH$

Altering C_2 to 1,470pF and using a *Mullard* LA2300 Vinkor pot core to obtain 425mH resulted in a filter with a notch in excess of 70dB and a minimum stop-band attentuation of 33dB.

To derive an optimum filter for frequencies other than 2,125Hz and 2,975Hz would require a further detailed calculation. However, a suitable filter will result if the reactances of the 2,125/2,975 filter are changed in proportion to the shift in frequency.

Example: filter for 1,275Hz and 2,125Hz.
Choose the 1dB cut-off frequency to be a little hf of 2,125Hz, say 2,150Hz. The 1dB cut-off frequency of the 2,125/2,975 was 3,000Hz, therefore, multiply the reactances by 3,000/2,150 = 1·4 ie $C_1 = C_3 = 0{\cdot}014\mu F$
$C_2 = 2{,}000pF$, and L = 620mH.

This, unfortunately, results in a filter with a notch at 4,560Hz ie not the desired 3,825Hz, but even so the third harmonic of the mark frequency is still an adequate 35dB below the fundamental.

The complete circuit of the 2,125/2,975 afsk oscillator is shown in **Fig 7.14**.

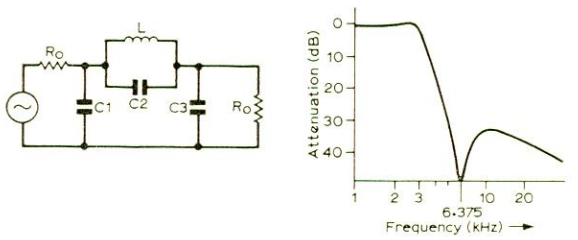


Fig 7.15. Circuit and response curve of low-pass filter.

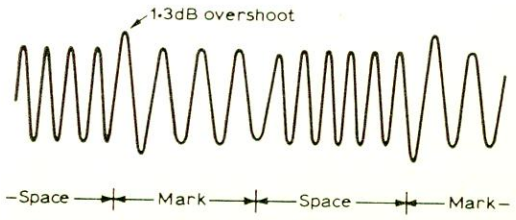


Fig 7.16. Output waveform showing 1·3dB overshoot when switching from space to mark.

Performance

Output level	0–50mV rms
	less than 0·5dB between mark and space
Distortion	Typically 1 per cent
Frequence stability	
versus temperature	0·1 per cent per °C at 25°C ambient
versus supply voltage	0·25 per cent per volt at 12V (Note 1)
Current drain	8mA at 12V
Keying input	Zero or negative gives 2,125Hz output. Positive 0·6V to more than +100V gives 2,975Hz output (Note 2)
Transients	Output is phase continuous, ie there are no sharp transitions when switching between mark and space but there is a 1·3dB overshoot when switching from space to mark, **Fig 7.16**

NOTE 1: It is recommended that a stabilized supply be used for the 12V rail. A zener diode and resistor should be sufficient, **Fig 7.17a**.

NOTE 2: The circuit will accept both polar (eg +80V for space and −80V for mark) and single current signals (eg +10V for space and zero for mark). If it is necessary to operate the oscillator from a single current negative source or a polar source where the negative signal represents space, then the circuit can be modified as follows:

interchange TR1 and TR3
interchange TR2 and TR4
reverse diodes D1 to D4
reverse the 10F capacitor
use a −12V supply

Alignment

1. With the oscillator in the space condition, adjust VR1

to get an output of 2,975Hz. This is best done using a digital frequency meter but a good alternative is to display the appropriate Lissajous figure on an oscilloscope [2], a convenient reference oscillator can be made using a 425Hz tuning fork [3, 4].

2. Switch the circuit to mark and adjust VR2 for a 2,125Hz output.

3. The original design intended that the filter notch be centred on 6·375kHz. This can only be done using some form of wave analyser or distortion factor meter. However, it has

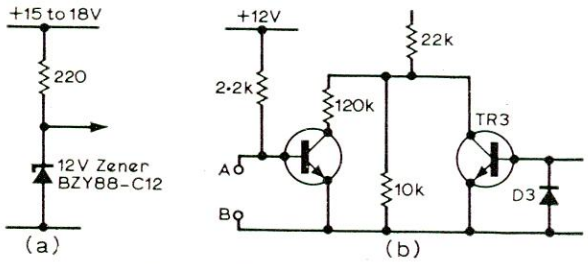


Fig 7.17*a*. Zener diode stabilizer.
Fig 7.17*b*. Narrow shift cw identification circuit.

been found that there is no significant increase in harmonic output if the notch is not exactly on 6·375kHz. It was also found that by adjusting the inductor, the mark and space outputs could be made exactly equal in amplitude. Therefore, if no distortion measuring equipment is available, then the equal amplitude criterion may be the better to aim for.

4. Adjust VR3 to give required output level.

Construction

The layout is not at all critical but by using the printed circuit layout of **Figs 7.18** and **7.19**, the oscillator together with terminal connectors can be housed in a 4⅜in by 2⅜in by 1in *Eddystone* diecast box (catalogue number 7134P). Component details are:

VR1, VR2 and VR3	*RS Components* side entry trimpots (p-c L/pots)
Inductor	*Mullard* LA2300 Vinkor mounted on clip and board assembly (DT2369/2366/2367)
1,470pF capacitor	1,000pF and 470pF polystyrene capacitors in parallel wired directly to inductor
Jack sockets	*RS Components* two- and three-pole types

Modifications

1. By connecting the resistor R_x, **Fig 7.14**, between the keying input and the 12V supply the oscillator can be switched from space to mark by shorting the key input to ground. It is advisable to use a fairly low value resistor for R_x (a few kΩ) to ensure wetting of the switching contacts.

2. Narrow shift cw identification, **Fig 7.17b**. When the key points A and B are opened, the mark frequency will be raised approximately 120Hz. This is wide enough to be read as fsk morse but narrow enough so as to leave most rtty terminal units in the mark condition, thus avoiding garble during cw identification.

A SYNCHRONOUS-PHASE AFSK OSCILLATOR FOR RTTY

As previously stated in this chapter, audio frequency shift oscillators used to encode rtty signals must operate in conformity with good design practice to avoid adjacent-channel interference. When an afsk oscillator is used with an ssb exciter to transmit carrier-shift fsk on the hf bands, the afsko must generate stable, sinusoidal tones. The ratio of space-tone to mark-tone amplitude must be variable to allow compensation for the combined frequency response of the microphone audio amplifiers and the crystal filter. This capability is required for adjusting the afsko so that the carrier power will be constant for both space and mark transmission. Finally, the most important afsko requirement for minimizing spurious signal generation on hf rtty is that the transition from one tone to the other be accomplished without a phase discontinuity. The synchronous-phase afsko described here has all the capabilities for generating the high-quality afsk waveforms required for transmitting carrier-shift fsk using an ssb exciter or transceiver.

The oscillogram of **Fig 7.20** shows the input-output characteristics of the synchronous-phase afsk oscillator. A positive input voltage greater than 0·7V constitutes a space command. The mark tone is generated for an input voltage less than 0·7V or a negative voltage.

Control Circuit Logic

The afsko uses a Signetics SP620A flip-flop IC. The 620A is a dc-triggered master-slave flip-flop that can be switched synchronously by using the J and K inputs together with a clock. The rising clock pulse cuts the slave off from the master. As the clock pulse rises still higher, it allows the logic at the J and K inputs to be set into the master. Then when the clock pulse returns to its low level, the state of the master is transferred to that of the slave which, in turn, sets the output levels. Transfer gate and master flip-flop gate thresholds are separated by sufficient voltage to guarantee that input and transfer cannot occur simultaneously.

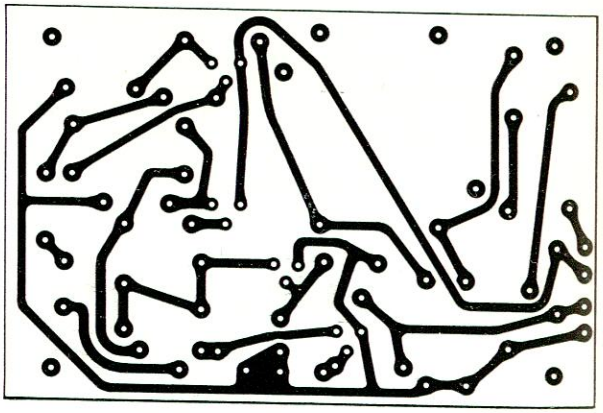


Fig 7.18. afs keyer, printed circuit board.

The flip-flop logic diagram, composed of AND and NOR gates, is shown in **Fig 7.21**. **Fig 7.22** shows the input, clock and output waveforms for synchronous operation. The inputs can be switched at any time, but the outputs switch to obey the input command only on the trailing edge of a positive clock pulse. The flip-flop functions as an electronic delay line. When a change in the input signal occurs, it is variable and can range from 65ns to infinity, depending upon the clock pulse-to-pulse interval.

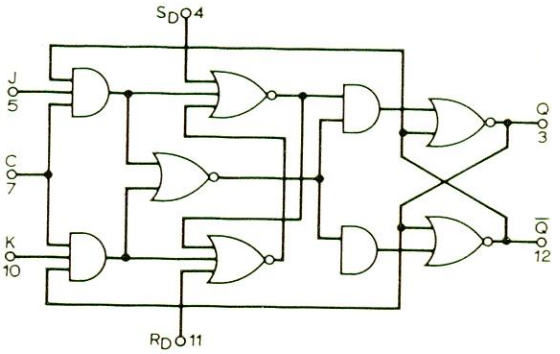


Fig 7.21. Logic diagram for the Signetics SP620A flip-flop 1C used in the afsko control circuit.

The afsko Circuit

Figs 7.23 and **7.24** are the functional block diagram and schematic of the synchronous-phase afsko. The input signal to the afsko is processed by Q5-Q6, which provide complementary inputs to the flip-flop. Q5 is a threshold detector that conducts for any input voltage greater than 0·7V. Q5 is off for any input voltage less than the 0·7V threshold. D8 protects Q5 by preventing excessive reverse bias being applied to the Q5 emitter-base junction. D8 also allows the afsko to be driven by a source having an ac-coupled output, since D8 provides a discharge path for the driving-source output capacitor. S1 is a reversing switch that allows the

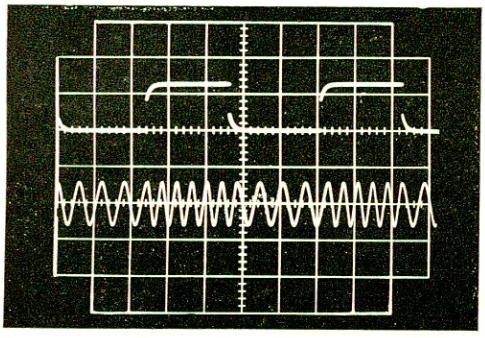


Fig 7.20. Input-output characteristics of the synchronous-phase afsk oscillator. Top is the input signal, 5V/division. Bottom is output signal, 1V/division, 1,650Hz mark, 2,500Hz space. Horizontal scale is 1ms/division.

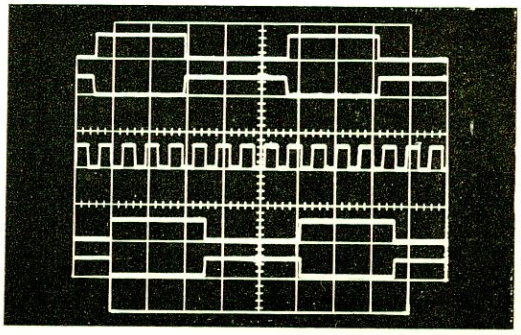


Fig 7.22. Switching characteristics of the SP620A 1C. Vertical scale all traces, 0 to +6V, 10V/division. Horizontal scale is 1ms/division.

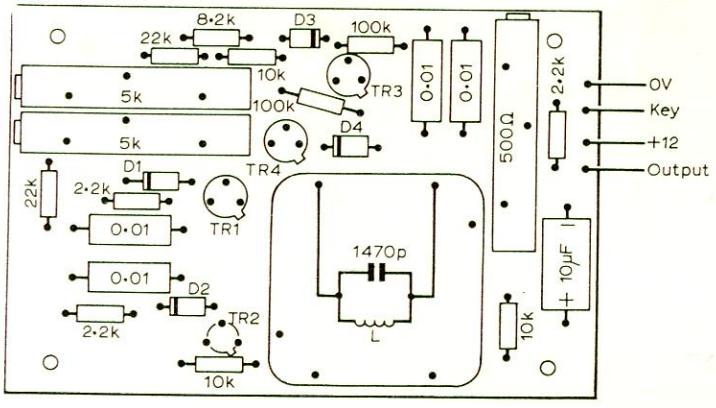


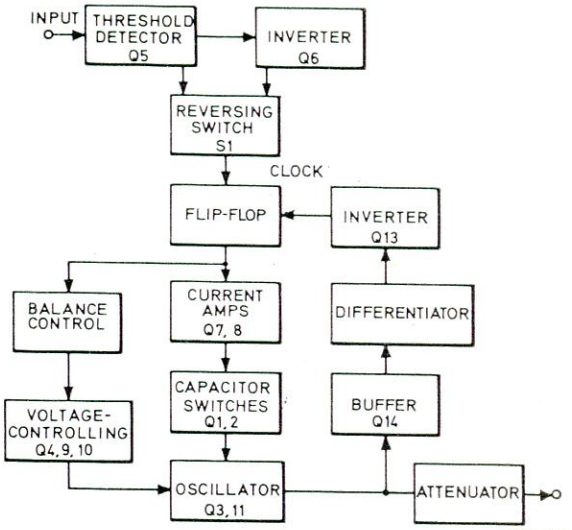
Fig 7.19. afs keyer component layout.
(see opposite page)

space and mark signals to be inverted; thus the afsko can be used on either lower or upper sideband.

Sine-wave Oscillator and Buffer

The basic sine-wave oscillator consists of the complementary amplifier (Q3 and Q11) and a tuned LC circuit. The tuned circuit, composed of L1 and one of three capacitors (C_{sn}, C_{sw}, or C_m), is switched in parallel with L1. Only one of the three capacitors is in parallel with L1 at any given time. Q1 switches the mark-tone capacitor, C_m, into and out of the oscillator circuit. S2B selects the desired space-tone capacitor; C_{sn} for narrow-shift operation, or C_{sw} for wide-shift operation. Q2 switches the selected space-tone capacitor in parallel with L1 only during space intervals. Actually, these capacitors are switched to the +6V power supply, but C1 provides an ac short circuit from the power supply to the grounded side of L1.

The oscillator drives a buffer stage, Q14, which prevents oscillator loading. The buffer drives a differentiator, Q12. The function of this differentiating circuit is to generate a signal when the output sine wave reaches its positive peak.



ABOVE

Fig 7.23. Block diagram of the synchronous-phase afsko.

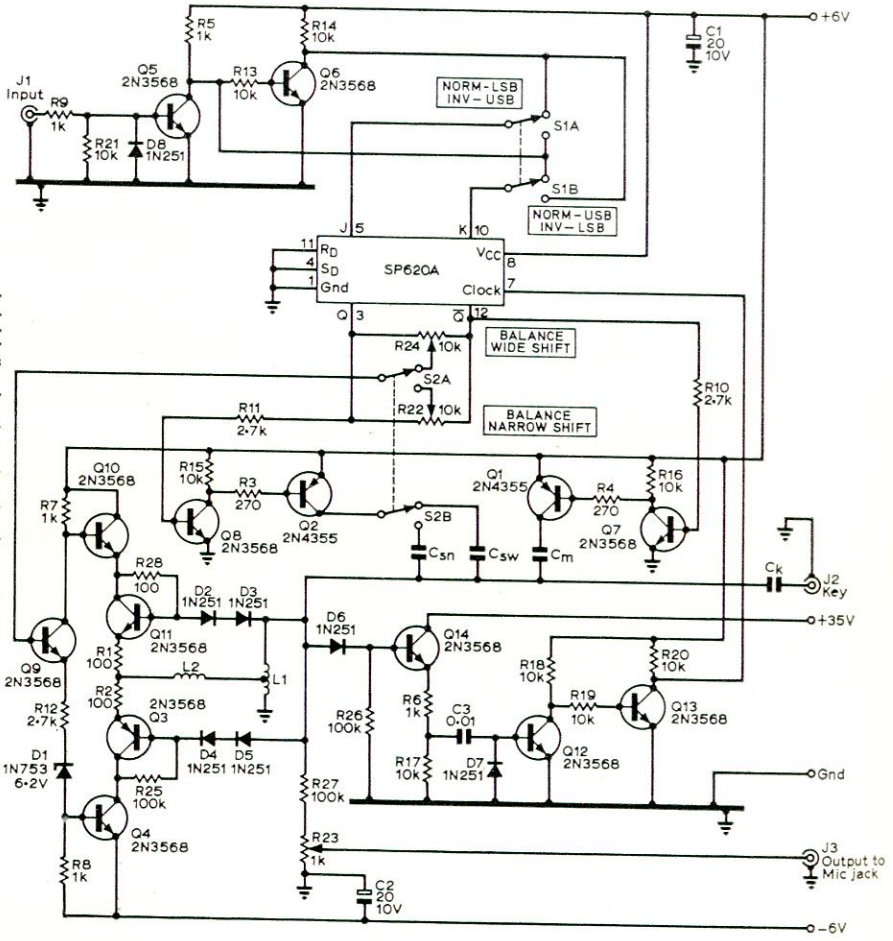


Fig 7.24. C_{sn}, C_{sw}, C_m select for desired narrow-shift space, wide-shift space, and mark tone frequencies. See Table 7.1 for capacitance values. Use capacitors having a voltage rating of 20V.
Ck select for the desired cw identification frequency shift.
J1-J3 $\frac{1}{4}$in phone-jack, or equivalent.
L_1 88mH.
L_2 22mH. Use only one winding of an 88mH toroid.
D_1 1N753, 6·2V zener or equivalent.
D_2-D_8 1N251 (30V piv or equivalent).
Q_1-Q_3 2N4355 or equivalent.
Q_4-Q_{14} 2N3568 or equivalent.
SP620A Signetics flip-flop (see text).

At this point in time, Q12 is turned off and the inverter, Q13, is turned on, thereby providing a +6 to −0V transition signal to the clock terminal of the flip-flop. This high-to-low transition is the trailing edge of the positive clock pulse.

Timing

Fig 7.25 shows the time relationship between the output sine wave and the clock pulse. The afsko is allowed to switch frequencies, from mark to space or vice versa, only at the time when the output sine wave reaches its peak; and only if the afsko input signal was changed during the previous period of the output waveform.

The Q and $\overline{Q}$ flip-flop outputs drive the current amplifiers Q8 and Q7. These current amplifiers provide the high base current required by the capacitor switches, Q1 and Q2. These switching transistors must support the circulating L1-C tank circuit currents.

At any given time, one of the capacitor-switching transistors (Q1 or Q2) will be on, while the other is off. Because the capacitor switching occurs at the positive peaks of the periodic output waveform, the collector-to-emitter voltage on Q1 and Q2 is always zero or some negative value. **Fig 7.26** shows how the collector voltages of both Q1 and Q2 vary with respect to time as the afsko is electrically commanded to switch from space to mark and vice versa.

Narrow and Wide Shift

Switch S2A selects one of two balance potentiometers; R22 for narrow shift and R24 for wide-shift operation. The selected balance potentiometer provides a voltage to the voltage-controlling circuit composed of Q4, Q9 and Q10. This circuit controls the voltage that provides power to the sine-wave oscillator, so that the mark-to-space tone amplitude ratio can be varied. When the afsko is used to drive an ssb exciter, this ratio should be adjusted for equal space and mark carrier power. **Fig 7.27** shows the high-quality afsk modulation waveform generated when the balance control is adjusted properly. Also shown are conditions of unbalance that can be used to compensate for a non-uniform combined frequency response of the microphone amplifiers and the sideband filters. When unbalanced, the output waveform reaches its equilibrium amplitude within 2ms (less than 10 per cent of the bit time for 60wpm teletype) after a change in tone frequency. R23 controls the afsko output amplitude, which can be varied from 0–1V p-p. The output waveform is a high-quality sinusoid.

Fig 7.28 shows the waveform quality for a mark tone of 1,650Hz and a space tone of 2,500Hz. The results of dis-

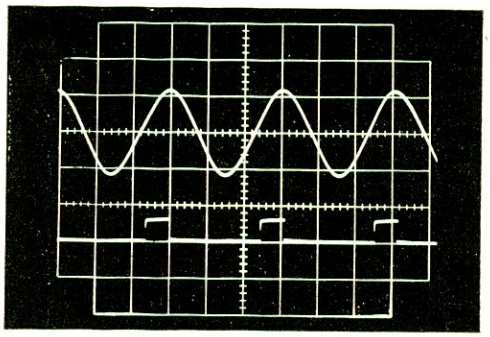


Fig 7.25. Time relationship between clock pulse and afsk oscillator output signal waveform. Clock trailing edge occurs at positive peak of output waveform. Top is output signal 0·5V/division. Bottom is clock signal, 10V/division. Horizontal scale is 0·2ms/division.

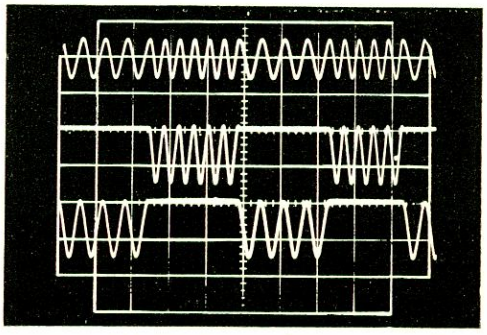


Fig 7.26. Time relationship between output signal and collector voltage on mark-space capacitor switches Q1 and Q2. Top is output signal, 1V/division. Centre is Q2 collector, 10V/division. Bottom is Q1 collector, 10V/division. Horizontal scale is 1ms/division.

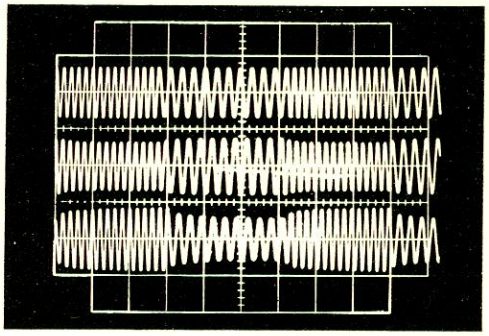


Fig 7.27. Effect of balance control setting afsk oscillator output waveform. Mark, space and switching frequencies are respectively 1,650, 2,500 and 100Hz. Top is output waveform of properly balanced afsk oscillator. Centre is balance control set fully counter-clockwise. Bottom is balance control set fully clockwise. Vertical scale is 0·5V/division; horizontal scale is 2ms/division.

TABLE 7.1

Recommended Tone Frequencies and Capacitor Values *

Upper Sideband		Lower Sideband	
mark tone	2,500Hz	mark tone	1,650Hz
key-down tone	2,000Hz	key-down tone	1,450Hz
space tones	2,330Hz (narrow shift)	space tones	1,820Hz (narrow shift)
	1,650Hz (wide shift)		2,500Hz (wide shift)
	C_m = 0.045F 20V		C_m = 0·11F 20V
	C_k = 0·036F 20V		C_k = 0·036F 20V
	C_{sn} = 0·055F 20V		C_{sn} = 0·094F 20V
	C_{sw} = 0·11F 20V		C_{sw} = 0·045F 20V

* Most capacitors have 20 per cent tolerance, requiring hand selection for best frequency accuracy.

tortion-analyser measurements made on the output signal from the afsko show a waveform distortion of less than 4 per cent for any tone frequency below 3·5kHz. The frequency stability is better than 0·2 per cent, including the effects of balance control setting.

The waveforms at various points in the afsko when S1 is in the "normal (lsb)" position and S2 is set for wide-shift operation are shown in **Fig 7.29**.

Conclusion

The afsko can be operated with either lsb or usb ssb transceivers. The selection of tone frequencies should be made so that, in normal operation, the mark frequency doesn't change when switching from wide to narrow-shift. The three tone frequencies can be independently controlled by selecting the proper values for C_{sn}, C_{sw}, and C_m. **Fig 7.30** can be used to select the proper capacitance value for the three selected tone frequencies. **Table 7.1** gives recommended capacitance values for usb and lsb operation. The recommended capacitor values aren't standard, so parallel combinations of two or more capacitors may be used, including very small capacitors for fine frequency adjustments.

The choice of semiconductors isn't critical, except that silicon transistors and diodes must be used. Bias conditions are designed to make use of the forward voltage drop (0·7V) across a silicon diode, and capacitor switching must be done with low-leakage silicon transistors. The physical layout of the components isn't critical, and special construction techniques aren't required.

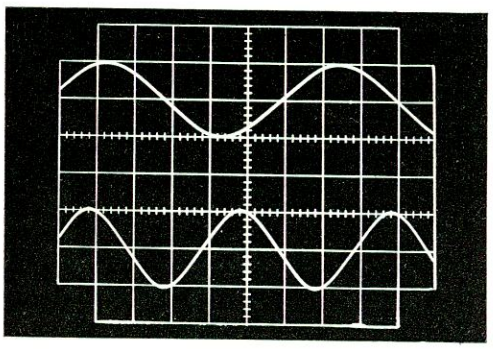


Fig 7.28. Output waveforms of the afsk oscillator showing quality of mark and space tones. Top is mark tone, 1,650Hz. Bottom is space tone, 2,500Hz. Vertical scale is 0·5V/division; horizontal scale is 0·1ms/division.

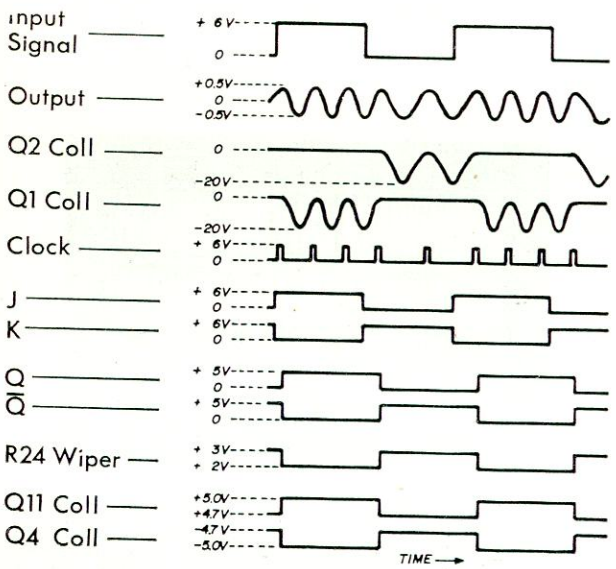


Fig 7.29. Timing diagram of the afsk oscillator.

FREQUENCY SHIFTING CRYSTAL CONTROLLED OCILLATORS

The amount of shift obtainable from a crystal oscillator depends largely upon the type of crystal as well as the circuit in which it is used. Generally it can be stated that the lower the frequency of the crystal, the more difficult it is to obtain maximum shift. Although there could be a limited number of cases where a crystal oscillator would be used on the hf bands, such as for autostart, the majority of applications would be at vhf. This being so, it may be seen that the problem of obtaining a large shift with a crystal does not apply, as any shift generated will be multiplied by successive multiplier stages up to the final operating frequency. For example, if the final output frequency of a vhf transmitter is in the 2m band, and the crystal used is in the 8MHz range, this assumes a crystal multiplication of 18 times, then for a final frequency shift of 850Hz, the crystal must be shifted by 850/18Hz, which is approximately 47·4Hz.

The circuit shown in **Fig 7.31** will work quite well with

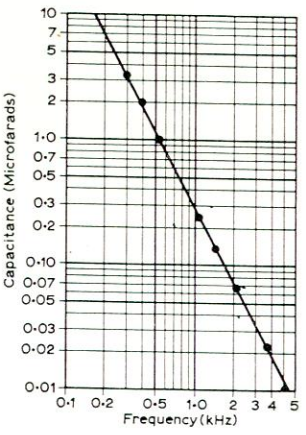


Fig 7.30. Curve for determining capacitance for the three-tone frequencies.

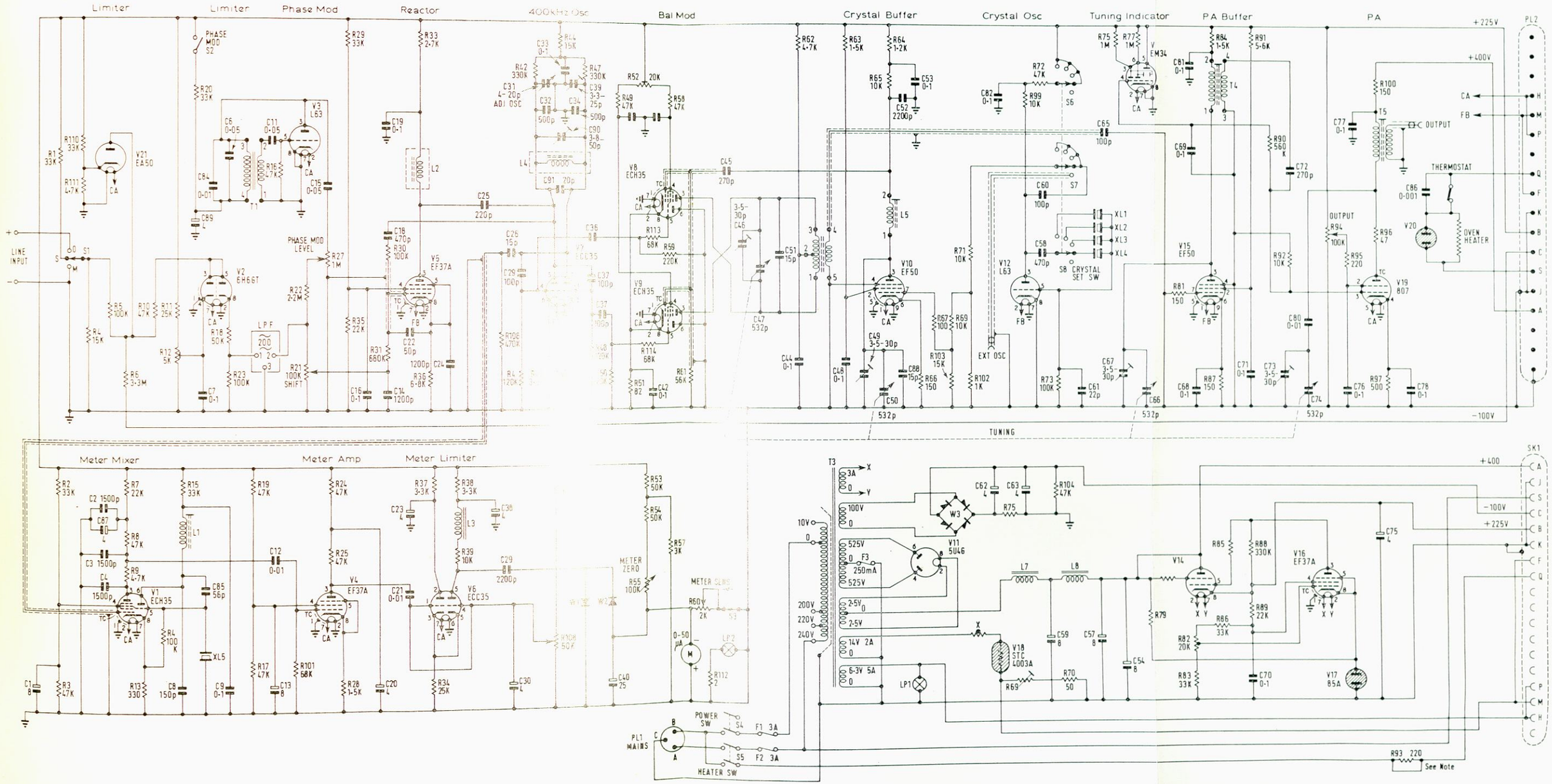


Fig 7.33. Circuit diagram of the FSX-2.

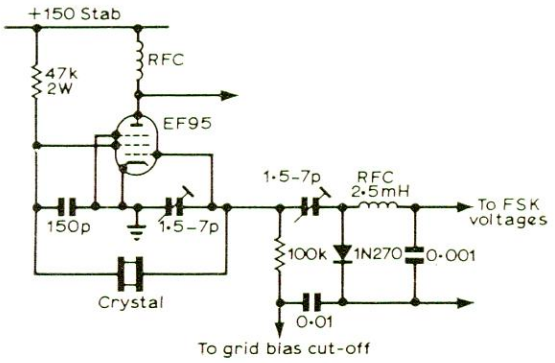


Fig 7.31. Circuit diagram of a crystal frequency shift keyer.

most crystals, but for maximum stability the following points should be considered:

1. The diode in the shifter should be a germanium type.
2. The rf choke should be wound on a plastic former, not ferrite.
3. The crystal trimmer capacitor should be as low a capacity as possible.
4. "Active" wires should be as short as practical.
5. Plate type crystals are to be preferred to the surplus pressure type.
6. Any extra fixed trimming capacitors should be mica types.
7. Air spaced trimmers should be avoided. For general use, NPO ceramic trimmers are satisfactory, or quartz dielectric trimmers for deluxe applications.

FREQUENCY SHIFT KEYING UNIT FSK-2

This unit designed by B.T.R. Ltd and made by A. T. & E. Co Ltd is basically an rf drive source for a following transmitter and incorporates facilities for frequency shift keying from teleprinters or similar machines.

The rack mounting assembly consists of two units. The rf unit, which can be slid out on runners, is on top with all its associated power supplies below. The overall dimensions are 19in by 19in by 22¾in high. Although somewhat large the FSK–2 is a useful piece of equipment providing a high quality fs signal source for rtty and can be employed with little modification on the amateur bands. Its application can be extended by the addition of a few changes which will be given.

The rf unit incorporates a thermostatically controlled oven which houses up to four crystals selected by a switch. Provision is also made for an external vfo selected by the same switch. Output is between 2–6MHz but a simple modification to the power amplifier will permit drive to be obtained between 4–12MHz.

Circuit

Fig 7.32 is a block schematic of the rf unit. **Fig 7.33** is a detailed circuit diagram of the complete rf and ps unit.

Input signals which can be either double or single current from a teleprinter or other source are fed through a double limiter and low-pass filter to a reactor which varies the frequency of a 400kHz oscillator in accordance with the input signal.

The degree of shift is controllable from the front panel between 0–1,000Hz. The 400kHz output is mixed with the output from the crystal oscillator (or vfo) operating between 2·4 and 6·4MHz in a balanced modulator. Ganged tuned circuits ensure that only the lower sideband is selected. This sideband drives the power amplifier via a buffer stage and an output of 4W into 70Ω is available.

It must be noted that all crystals used as well as the vfo must be 400kHz *above* the operating frequency. This has the advantage that an external vfo may be left running continuously and during receiving periods only the ht to the 400kHz oscillator need be removed.

If required a 200Hz oscillator is provided to phase modulate the reactor up to 1 radian. In amateur rtty practice this is unlikely to be used as it gives problems at the receiving end with certain terminal units.

A large meter is provided to indicate shift. A part of the 400kHz oscillator is mixed with a 397kHz crystal oscillator and the resulting af beat signal is fed to a counter circuit showing the degree of shift.

A "magic eye" indicator shows when the unit is correctly tuned.

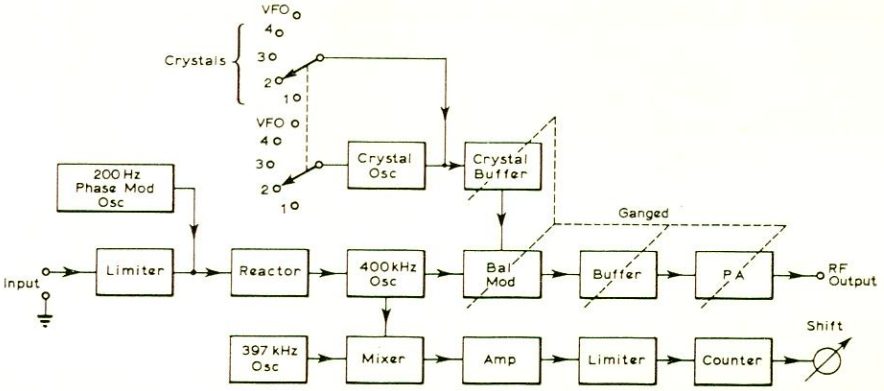


Fig 7.32. Block diagram of the FSK-2.

Keying Limiter consists of an EA50 diode (V21), an EB34 double diode (V2) which accept input signals of 50–150V. There is provision for test "Mark" and "Space" signals for setting up by means of a switch on the front panel.

Low-pass filter. This follows the limiter and restricts the bandwidth of the transmitted signal. This filter may be removed if required.

Reactor is an EF37 (V5) connected to a quadrature circuit coupled to the 400kHz oscillator. The EF37 slope is varied by the keying limiter thus changing the nominal 400kHz in sympathy with the input signal. The amount of shift is controlled from the front panel. Both lt and ht supplies to this stage are stabilized.

400kHz Oscillator uses a double triode ECC35 (V7) with the main L and C components housed in the crystal oven to give a high degree of stability. The frequency of this oscillator can be varied manually from the panel to give a change of ±1kHz. This is a useful feature as it allows "netting" over a small frequency range even when crystal controlled.

Crystal Oscillator uses a triode L63 (V12) in a normal Pierce circuit. Crystals up to four in number can be selected from the front panel. This also has a position for using an external vfo which removes the ht from the L63. It must be remembered that when selecting crystals for use in this unit their frequencies must be 400kHz *above* the operating frequency desired. This also applies to the vfo.

Buffer. Follows the crystal oscillator and uses an EF50 (V10) as a class A amplifier. Its anode load is tuned to suppress the upper sideband.

Balanced Modulator. Two triode hexodes ECH35 (V8 and 9) are used. Balance is arrived at by differential screen voltages. The crystal oscillator feeds the hexode signal grids and the 400kHz oscillator is fed to the triode grids. The output load is a wide band transformer covering 2–6MHz inductively coupled to the P.A. buffer.

Buffer is an EF50 (V15) with gang tuned anode driving the power amplifier.

Power Amplifier. This is an 807 (V19) covering 2–4MHz. Its screen voltage can be varied to control output.

Power Supplies. A 400V supply is provided by a 5U4G (V11) for the p.a. stage. From this supply is derived a 225V line, stabilized by a KT66 (V14) EF37 (V16) and 85A1 (V17).

There is a separate negative supply of −100V for the limiter obtained from a selenium rectifier and separate transformer winding.

Heater windings are normal except for a 14V lt which gives a stabilized 6·3V for V5, V7 and V12 using a thermistor and barreter 4003A (V18).

The FSK 2·2 input is suitable for 190–240V 40–60Hz.

Modifications

The following modifications make the FSK-2 more useful as a driver unit for amateur rtty.

1. An additional switch on the ps unit in the centre top of the 525–0–525V ht transformer winding. This leaves heaters on and removes ht during transceiving periods. The "power" switch on the unit as constructed controls both ht and lt supplies.
2. Removal of the lp filter. This is located under the rf chassis adjacent to the breeze supply socket. It has tags labelled 1, 2 and 3. To remove from the circuit, disconnect the earth wire from No. 2 and short-circuit tags 1 and 3.
3. Output on 4–12MHz can be obtained by a change to the p.a. (807–V19) anode circuit T5. If the anode coil is tapped at the eighth turn from the *top* and the ht feed via R100 taken to this point the 807 will act as a doubler. This function can be controlled by a switch. T5 is slug tuned and should be retuned for optimum output on 3·5 and 7MHz. Careful adjustment of the tap point will ensure that this is so.
4. When using an external vfo which may have limited output, it will be found that there is insufficient drive for V10. If, however, S7 is rewired so that C60 is taken directly to the top of R71, vfo input taken to the moving part of S.7, and position 5 (vfo) wired to the junction of R67 and R69 the basic troubles are overcome. It should be noted that in the vfo position S8 removes ht from the crystal oscillator.
5. If the phase-modulating oscillator V3 is not used it may be keyed externally as an identification signal at the end of an rtty transmission. Being superimposed on the "mark" signal the receiving printer is not disturbed.

References

1. *Design, Theory and Data for Electrical Filters*, J. K. Skwirzyhski, 1965.
2. *Radio Communication Handbook*, RSGB (1968), p19.29.
3. *Short Wave Magazine*, March 1966, p18.20, "RTTY Topics", W. M. Brennan, G3CQE.
4. Spacemark Limited, Altrincham, Cheshire.

CHAPTER 8

FILTERS

Construction and Measuring

THE 88 Millihenry Toroidal inductor has become almost as well known in rtty and audio filter construction projects as the fixed resistor or a simple capacitor. Indeed, this component sees almost universal use in demodulator channel filters, replaced only occasionally by tv width coils.

A close inspection of these units will reveal that they consist of two independent windings, each winding occupying half of the toroidal form. Independently, these windings exhibit an inductance of 22mH. When connected in series, the inductance quadruples to give a value of 88mH. Mutual coupling accounts for the reason the two windings in series give more than just the sum of the single-winding inductances. See **Fig 8.1**, which shows the physical connections to be made.

A simple L—C filter consisting of an 88mH toroid resonated with one or more capacitors at a fixed audio frequency may be used for a variety of purposes. The schematic of such a filter is shown in **Fig 8.2** where the numbers indicate a pin basing arrangement commonly used if the parts are mounted on an octal plug. (The single capacitor shown represents the value of perhaps two or more capacitors connected in parallel. High quality capacitors should be used, such as mylars. A lossy capacitor will contribute to poor filter performance.) Depending on external connections, this filter may be used in either a series-resonant or a parallel-resonant configuration.

Plug-in filters are often used even though one does not expect to change filters frequently. The advantages are that mounting is convenient, only a small amount of chassis space is required for the complete filter, and the filter may be tuned independently on the bench without having to dig down under the chassis. Various methods of mounting may be used. The general idea shown in **Fig 8.3** is common. The bakelite centre locating pin of the plug must be drilled to clear a screw. Two washers made of heavy cardboard, phenolic board, Perspex, or other insulating material are required to mount the toroid. If the latter materials are used, a circular hacksaw with an inside diameter of 1¼in is handy. With a portable electric drill several washers can be made in a matter of minutes.

A standoff will be required between the plug and the first washer. This could be a short length of ⅜in wood dowel, with 1¼in round head wood screws used at each end to secure the assembly. Or it could be a ½in or $\frac{9}{16}$in length of ¾in copper tubing, with the entire assembly held together with a single nut and screw 2½in in length.

As **Fig 8.3** shows, the resonating capacitors are placed adjacent to the plug base, around the standoff.

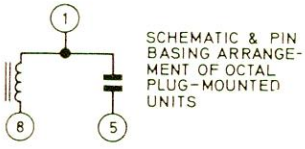


Fig 8.2. Schematic and pin-bearing arrangement of octal plug-mounted units.

Tuning a Filter

In all construction projects it is desirable to resonate the filter at a specific known frequency.

Fig 8.5 shows the test set-up for the tuning of a simple L—C filter. An accurate frequency source is desired, such as a very well calibrated audio oscillator, an oscillator checked against a digital frequency counter, a frequency derived from or beat with that of a tuning fork, the signal from a "standard audio frequency" magnetic tape, or perhaps a signal obtained through the use of notes from the piano. If an accurate frequency source is not available, another L—C filter which has been precisely tuned to the desired frequency may be used for reference, as explained

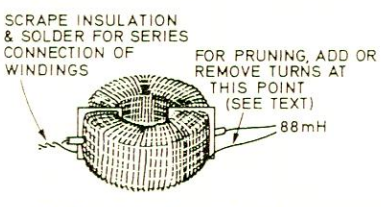
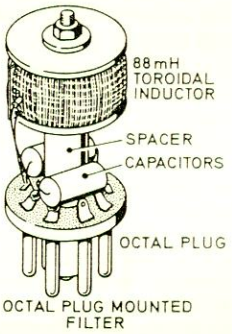


Fig 8.1. 88mH toroidal inductor.

Fig 8.3.
Octal plug mounted filter.



later. It may be helpful in getting a usable signal level to insert an impedance step-up transformer between the audio source and the 1MΩ isolation resistor. To avoid loading the filter, the voltmeter should be a high impedance instrument. A valve voltmeter is best. Sensitivity permitting, an even larger value than 1MΩ should be used for isolation, such as 2·2 or 2·7MΩ. With a low impedance meter and low isolation the tuning indication will be broad, yielding less accuracy.

As the audio source is tuned to the resonant frequency, a maximum meter reading will occur. Tuning of the filter may be done in several ways. Probably the easiest is to select a capacitor value from **Fig 8.4** for the desired frequency, and then either add or remove turns from the toroid as required. Number 30 enamelled wire can be neatly spliced to add turns. The enamel provides its own insulation when turns are added over the splice, but a touch of fast drying cement, or fingernail polish, over the splice will give added insulation. The placement of the few extra turns is not critical. Refer to **Fig 8.1**. It has been found that a difference of one turn on an 88mH toroid resonated at 1kHz shifts the resonant frequency by about 1·4Hz. When resonated at 5kHz, one turn shifts the frequency by about 6·8Hz. It appears that the frequency changer per turn added or removed is directly proportional to the resonant frequency. An average value of 1·35Hz/turn/kHz was noted. In other words, for a 2kHz filter, a resonant frequency shift of about 2·7Hz for each turn of wire added or removed, etc, could be expected.

Another method of tuning the filter would be to try experimentally several capacitors of the same nominal value until one was found which came to the desired frequency. By this method a rather large number to select from is needed. If none was found from the selection, the closest, but slightly on the high-frequency side, should be chosen, and the filter padded with much smaller value capacitors on a trial and error basis until the exact resonant frequency was reached.

Using a Reference Frequency Filter

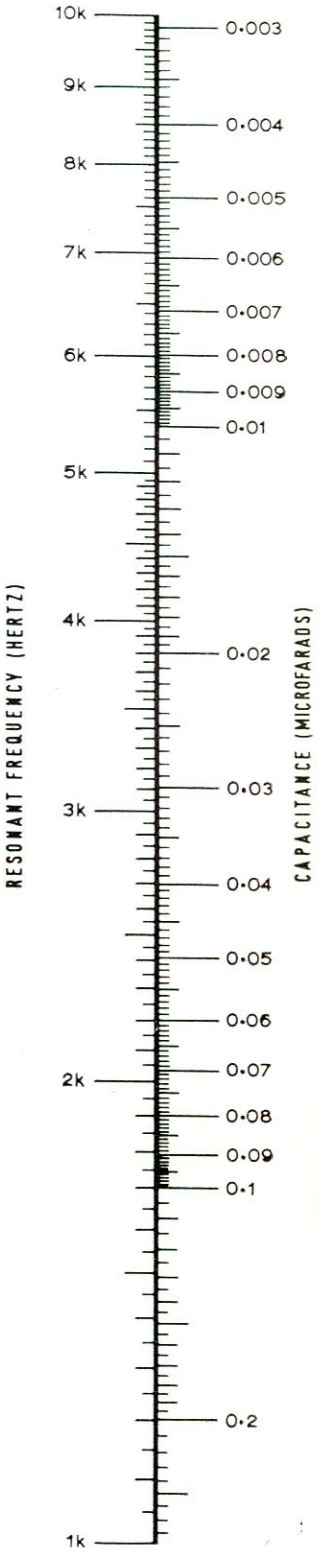
If a highly accurate frequency source is not available, a precision frequency L—C filter (one that has been very accurately resonated at the desired frequency) may be used as a reference for obtaining the wanted frequency. An uncalibrated audio oscillator or a unit of questionable calibration can easily be set to within a few cycles of the precision filter frequency. Or the receiver audio output may be used instead of an audio oscillator, by energizing the bfo and beating against a 100kHz marker or other stable signal.

Use the circuit of **Fig 8.6** and tune the audio source through the frequency range of the filter. A maximum meter reading will occur at the resonant frequency of the filter.

CAUTION: If the audio source has high harmonic content, false peaks will occur when the output frequency is a subharmonic of the filter frequency. If the approximate frequency of the source is not known, these peaks may be avoided by starting from a frequency much higher than that of the filter, and tuning down until the first meter peak occurs.

Once the frequency has been set, the audio signal may be transferred to other circuitry as desired. Depending on its stability, the source frequency may require periodic checking. If the frequency of another filter is being compared with that of the precision frequency filter, two such circuits can gener-

Fig 8.4. 88mH inductor nomogram.



ally be driven in parallel from the audio source, eliminating the need for transferring the output.

Receiver Tuning Display

The high Q of these filters makes them useful for a receiver tuning indicator for hf rtty, when used in conjunction with an oscilloscope. A pair of filters is required, one for the mark frequency of the demodulator and one for the space frequency, see **Fig 8.7**. This circuit gives the plus pattern display. Some amateurs prefer to reverse the oscilloscope inputs from those shown. The potentiometer is used to balance the displayed audio. If desired, the fixed resistors shown may be eliminated and a 1MΩ or so potentiometer used. Unloaded, the display will be almost a true plus pattern, with vertical and horizontal lines as the signal frequency shifts. Most amateurs using this display, however, prefer to load the circuits so that the vertical and horizontal displays are narrow ellipses with a width about an eighth the size of the length, instead of straight lines. This can be done by using a lower value potentiometer, 100kΩ or 250kΩ or adding resistors in series with the toroids as shown. A little experimentation with the resistor values will give this broadened display. In use, if the receiver is not correctly tuned, the ellipses become distorted in a manner that is characteristic of the amount and direction of mistuning. After a while, experience is gained with this broadened display. A glance will tell in which direction the receiver need be tuned and approximately how far, whether the sending station is transmitting a steady mark, from the keyboard or from a tape. Also this set-up will indicate whether shift is too narrow or too wide.

Channel Filter Responses

The equations are listed only to show that definite mathematical relationships do exist between the various values and responses of a simple L—C filter. There are several useful equations for the more industrious individuals who may wish to perform calculations regarding various responses, most of these having been learned as basic electronics and perhaps even forgotten by now. These equations apply to **Fig 8.8** where R is the resistive loss of the toroid, or the sum of the toroid loss plus any external loading resistor placed in series with the toroid in the position shown for R.

Equation 4 is good only at filter resonance, and is an approximation based on the assumption that the inductive reactance is much greater than the resistive loss of the coil. (This is true for the 88mH toroid at audio frequencies used for rtty work, even with normal resistor values purposely added externally for loading.)

1. $X_L = 2\pi fL = \omega L$
2. $X_c = \dfrac{1}{2\pi fC} = \dfrac{1}{\omega C}$
3. $Q = \dfrac{X_L}{R}$
4. $Z = Q_L X_L = \dfrac{X_L^2}{R} = \dfrac{L}{CR}$
5. $Z = \sqrt{\dfrac{R^2 + \omega^2 L^2}{(1 - \omega^2 LC)^2 + \omega^2 C^2 R^2}}$

Although the relationships of equation 4 may be used to calculate voltage responses at resonance, they are of no value for calculating filter bandwidths. Equation 5 is the general formula, assuming perfect filter isolation from remaining circuitry, and must be used to calculate the filter impedance off resonance. This equation will be found only in the more advance technical reference books. Once the impedances at various frequencies are determined by formula, one may then calculate the voltage responses and thereby determine the filter bandwidth at a given number of decibels down from peak response. However, all of these calculations become very long and involved, and are even more complex if filter loading due to imperfect isolation is taken into account.

Rather than performing laborious calculations to determine these responses, a limited number of amateurs with

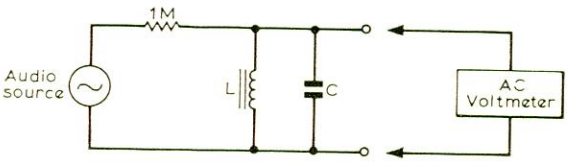


Fig 8.5. Circuit for tuning an L—C filter.

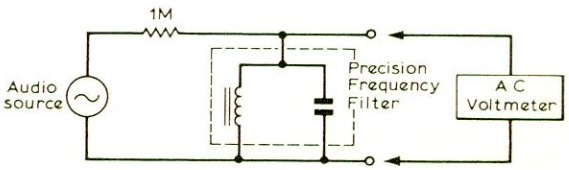


Fig 8.6. Using filter for frequency reference.

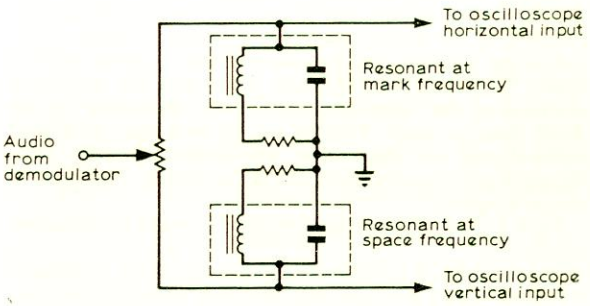


Fig 8.7. Receiver rtty tuning indicator circuit.

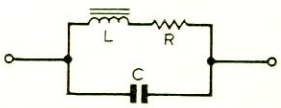


Fig 8.8. Simple L—C circuit.

access to sophisticated test equipment, such as digital frequency counters or very accurately calibrated audio signal generators, rely on empirically or experimentally derived external circuit component values to obtain the desired responses. However the majority of amateurs, lacking such equipment, find it necessary to consult published information to obtain the desired bandwidth responses.

It should be noted that for optimum response in audio discriminators, it is necessary to use more than merely a balance potentiometer and two toroids resonated with appropriate capacity. For symmetrical bandwidth and amplitude responses between mark and space for narrow frequency bandwidth filters, or for a linear discriminiator response, it is necessary to select with care each individual value of loading resistor and isolation resistor.

Previous published data has been confined to specific circuit values for selected bandwidths at specific audio frequencies. Such information does not really illustrate how the various responses of a simple L—C filter are affected by changes in circuit values. Nor do mathematical formulae, because the calculations are so complex.

For anyone performing response measurements on simple L—C circuits, it soon becomes apparent that several variable factors are concerned.

Listing the six principal variables, they are the values for L, C, isolation resistance, intentional loading resistance, amplitude response, and bandwidth response. There are of course other factors involved, such as filter loading due to imperfect isolation, but in a given circuit these are more or less constant. The first four of the above variables may be arbitrarily selected and interact to affect the last two. By making a careful selection of the values for the first four, the amplitude and bandwidth responses can be controlled.

The frequency of resonance of a channel filter is usually determined by the builder's preference. Using 88mH toroids, the capacitance required can be calculated or determined experimentally without highly sophisticated test equipment.

For each of the two channel filters, then, the number of variable factors has been reduced to four.

It only remains necessary to juggle values of isolation resistor and loading resistor to obtain the desired bandwidth response at the desired amplitude response. Unfortunately, this is not a simple task because a change in either resistor affects both responses and may also affect the amplitude response of the opposite channel filter, depending on the drive circuitry used. Thus it can be seen that even with sophisticated test equipment, the empirical design of a demodulator discriminator circuit to precise responses is rather laborious.

Fig 8.9 shows the test circuitry used to make the measurements.

This circuitry is presented to enable the reader to evaluate in terms of his own circuitry the data given later in this article. Actual demodulator circuitry was used in order to eliminate the effects of additional unknown variables, such as loading by the discriminator detectors, etc. Note that the diode detectors are capacitively coupled to the filter output, in contrast to the technique used in the TT/L–1 and 2 units (chapter 5), where an amplifier stage effectively isolates the filter from the detectors. The bandwidth response of the circuit of **Fig 8.9** will therefore be broader than for similar values of resistor in the TT/L units.

The input audio level to the limiter was sufficient for hard limiting. All measurements were based on the dc voltage response indicated as Eo, taken with a vtvm. Bandwidth measurements at the 3dB points were based on frequency differences versus ratios of dc voltages at the output. The circuit under test is shown in the dashed line rectangle. The inductor was an arbitrarily selected 88mH toroid, with C to resonate at the desired frequency. R1 represents the isolation resistance used, and R2 the loading resistance. Although parallel loading of the toroid could have been used, the series loading technique was arbitrarily chosen. Responses were measured for several combinations of values of R1 and R2. **Fig 8.10** shows the measured responses for a 1,275Hz filter.

At first glance this graph may appear a bit formidable, but it is not difficult to interpret and vividly portrays how changes in resistor values will affect the responses of a simple L—C filter. Each curved line drawn in the graph represents one value of fixed resistor associated with the channel filter. The lines running primarily in the horizontal direction represent various test values for R1, the isolation resistance, while the lines running primarily in the vertical direction represent values for R2, the loading resistor in series with the toroid. At the intersection of a pair of lines, the dc voltage response of the test circuit at resonance for the particular resistor values may be read from the scale at the left. For the same point, the 3dB bandwidth may be read from the scale at the bottom of the graph.

It may be seen that in the 50 to 100Hz bandwidth range, the bandwidth response is controlled primarily by the series loading resistor, R2. The isolation resistor, R1, has a great effect on the voltage response but not so great an effect on the bandwidth response in this range. At wider bandwidths, a change in either resistor has an appreciable effect on both responses.

The shift in direction of the curves in the upper left portion of the graph warrants an explanation. Because the measurements were taken "inside" the demodulator, with the grid of the succeeding trigger state connected, the high dc output voltages caused the trigger stage to draw grid current. This in turn is reflected as additional parallel loading of the channel filter, broadening the response. The higher the dc voltage, the lower the equivalent parallel resistance became, and thus the broader the response. This type of an effect would be very difficult to calculate by mathematical means.

There is no point in reproducing the similar graph obtained for the 2,125Hz filter. The only real difference is that the lines for identical value resistors appear to be shifted upward and to the right. In other words, a broader bandwidth with higher amplitude voltage response would be noted in the 2,125Hz filter for identical resistor values. Say that one used this identical demodulator circuit and wanted a 10 or 12V response at a bandwidth response of 100Hz. For 1,275Hz, it may be seen from the graph that a value of 100kΩ for R1 and 30Ω for R2 gives this result. If the same values of resistors were used in the 2,125Hz filter, the amplitude response would be 20V with a bandwidth of 162Hz. To duplicate the desired response at 2,125Hz, it would be necessary to use a value in the range of 390kΩ for R1 and 10Ω resistor for R2. The different values are required because of the impedance differences of the basic filter elements.

Optimizing Discriminator Response

A demodulator audio discriminator contains two such L—C filters, generally excited from the same drive point as

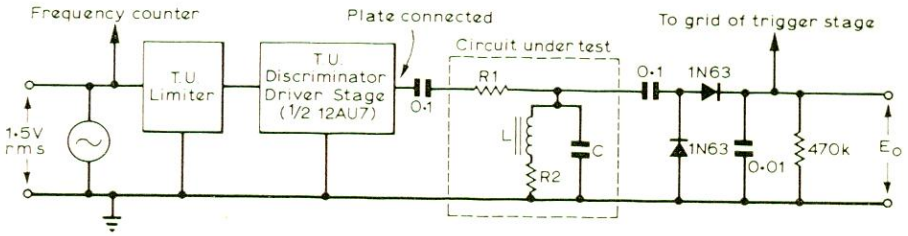


Fig 8.9. Circuitry used for response measurements.

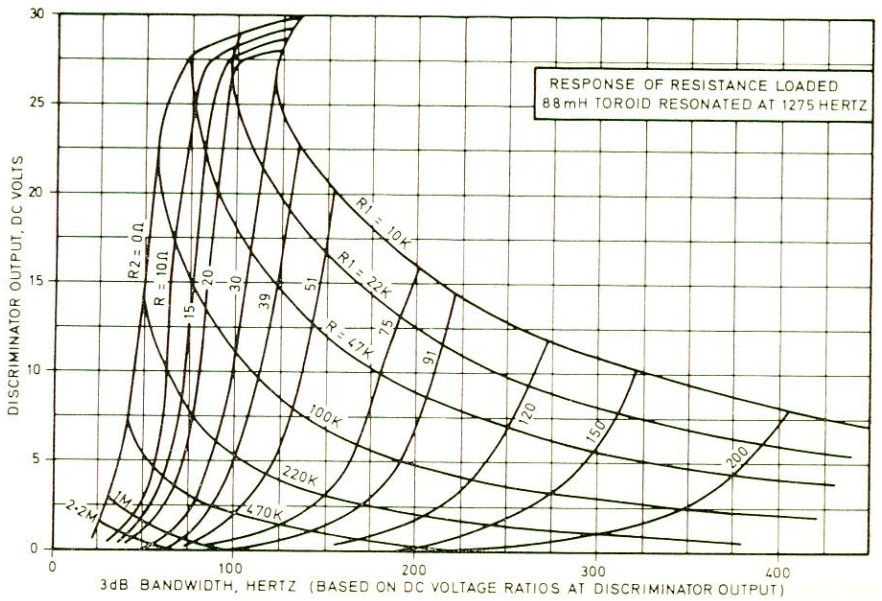


Fig 8.10.
Response of resistor loaded 88mH toroid resonated at 1,275Hz.

shown in **Fig 8.11**. One filter is tuned to the audio mark frequency and the other to the audio space frequency.

Most simple demodulator designs do not contain circuitry for the equalization of the mark and space bandwidth responses, provided by R2 and R4 in **Fig 8.11**. All circuits of good design, however, do contain a method of equalizing the mark and space amplitude responses, provided by a network of resistors similar to R1, R3 and R5. Some circuits call for only a potentiometer such as R5, while other circuits call for only two different-value fixed resistors, such as R1 and R3, but the end result is still amplitude equalization.

Figs 8.12a and **b** show the measured discriminator responses of a simple demodulator test circuit providing no bandwidth equalization. Referring to **Fig 8.11,** resistors R1, R2, R3 and R4 of the test circuit were each 0Ω (direct connection in place of resistor). R5 was a 250kΩ potentiometer, and the detectors were capacitively coupled directly to the outputs of the channel filter circuitry. **Fig 8.12a** shows the response for a 1,275–2,125Hz discriminator and **Fig 8.12b** shows that of a 2,125–2,975Hz discriminator. It may be seen that the lower

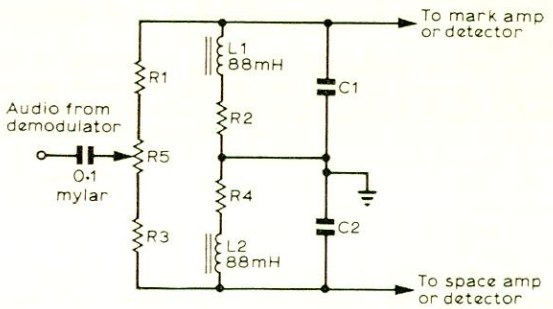


Fig 8.11. Optimum response channel filters: L1 and C1 to resonate at mark frequency; L2 and C2 to resonate at space frequency. See Tables 1 to 4 and text for resistor values.

frequency range exhibits a severe bandwidth non-uniformity, and the higher frequency range displays a quite obvious non-uniformity. The actual 3dB bandwidth responses were measured as follows, with equalized amplitude responses obtained by appropriate adjustment of the balance potentiometer.

1,275 mark, 38Hz bandwidth.
2,125 space, 67Hz bandwidth.
2,125 mark, 73Hz bandwidth.
2,975 space, 108Hz bandwidth.

By comparing the 45·45 baud rate of 60 wpm rtty signals with the above figures, it may be realized that bandwidth equalization as well as amplitude equalization should be considered in any discriminator design. Indeed, the 1,275Hz channel filter will not even pass the full bandwidth of an rtty audio signal, so some intelligence from the signal is filtered out. (As a simple but more severe analogy, imagine trying to copy a 2·1 kHz bandwidth ssb signal with the receiver bandpass filter set at 400Hz. Although some of the modulation intelligence might be detected, it would be done with a bit of difficulty.) Further, unequal bandwidths may introduce the effects of bias distortion on a signal because of the delay-

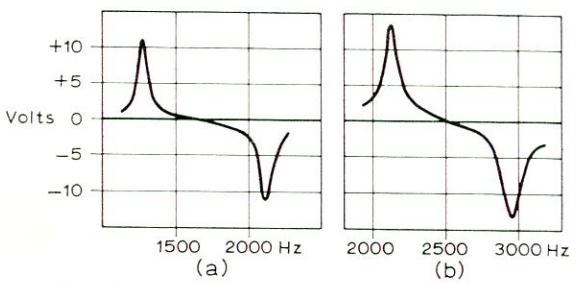


Fig 8.12. Responses of unloaded discriminator circuits.

ing action of filters. So it is easy to see that for optimum copy of rtty, some tailoring of the filter responses must be done.

There are two methods of equalizing the bandwidth responses of a pair of channel filters. The first involves removing the turns. This lowers the inductance, thereby shifting the L/C ratio to maintain resonance, and resulting in an impedance which matches that of the mark filter. With equal impedances, equal resistors can then be paralleled across each filter for symmetric control of the bandwidth responses.

The second method of equalizing bandwidths is also through external loading, but the 88mH toroids are not altered. Parallel loading can be used, but series loading of the inductor provides a finer degree of bandwidth control with stock resistor values which are available.

For optimum discriminator responses with series loading, each filter channel must contain selected values of isolation resistance and loading resistance. These are shown as R1 through R5 in **Fig 8.11**.

The advantages of operating with tailored channel filter responses can be enjoyed with any audio discriminator demodulator at any frequency range, perhaps by adding only a few resistors, a switch and two or three potentiometers and capacitors.

Switched Responses

The circuitry for changing filter pairs is simply that complete filters (comprising different components) are switched in and out. In all cases for discriminator filters, the switching action selects circuits which each contain an 88mH toroid. In some cases a few of the associated parts are identical in the switched circuits, such as resonating capacitors. Chassis space and components can be conserved and yet the same function accomplished by using a 5-pole switch instead of the previously required 3-pole unit.

The switching arrangement of **Fig 8.13** is suggested. This figure shows only two positions for the 5-pole switch, but additional responses are available by using more switch positions, and extending the circuit to correspond. It may not be required to add five new fixed value components for each new switch position. For example, where R4A and R4B are shown as the switched loading resistors for the space filter, the third switch position might select R4C (not shown on the schematic) to be a value equal to R4A. In this case, it would be necessary only to interconnect the A and C contacts of this switch section, and use the resistor already existing for R4A in both positions. Indeed, resistors R2A and R4B (different positions of different switch sections) might actually be the same value and could, therefore, be physically just one resistor. The disadvantages of this circuit are that plug-in filter construction is not convenient, and that the tuning for resonance of the second and succeeding switch positions must be done solely with capacitors (no toroid pruning). The advantages of this circuit over that of switching to independent channel filters is that only two toroids are required for all switch positions, that it is never necessary to resonate more than one circuit to the same frequency, and that it is not necessary to duplicate like parts for different switch positions.

Universal Designs

The channel filters themselves and associated resistors might be considered simply as a pair of frequency-sensitive voltage dividers. All input signals are divided down in

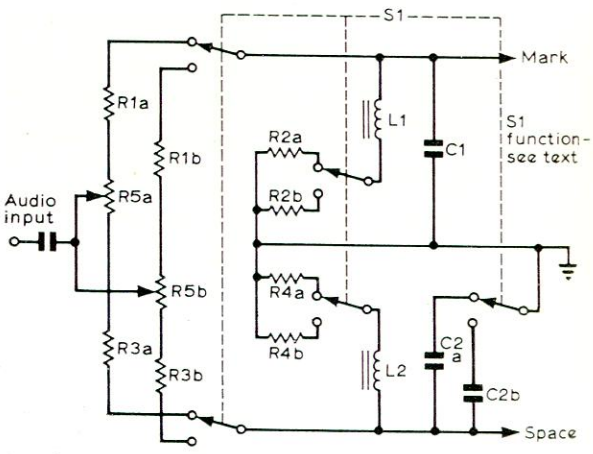


Fig 8.13. Discriminator response switching.

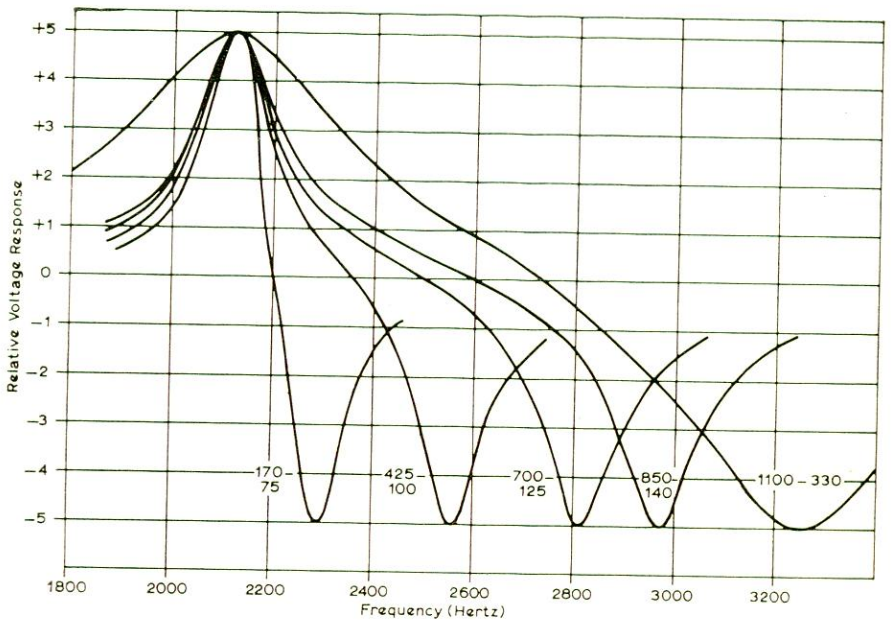


Fig 8.14. Tailored discriminator responses, progressive shift switching

amplitude, but off-resonance frequencies are divided down further than the frequencies to which the filters are tuned. The design of a tailored response channel filter necessarily establishes the amount of voltage division. The permissible amount of voltage division in the channel filter section may vary from one demodulator design to another. A given discriminator L—C circuit design might, therefore, work very well in one unit, but might perform miserably in a unit of another design because the dc pulses reaching the trigger or slicer stage are reduced too far in amplitude by the voltage divider action of the channel filters. In this case, an amplifier stage added to the second unit to compensate for the losses of the filters would be necessary.

A second reason why "universal" optimized response discriminator designs may not exist is because of external loading differences in various demodulator designs, affecting the bandwidth responses. Both input and output circuitry must be considered. The output circuitry is usually more important though, if values of R1, R3 and R5 are kept high. Circuit design of the optimized discriminator can compensate for external loading situations.

There are two general types of load that channel filters may work into. One is the high impedance input circuit of an amplifier stage, as used in the TT/L units. The other is the lower impedance of the detector circuitry itself, through a coupling capacitor. There may of course be a range of load impedances for either type of load, in various demodulator designs.

Although not necessarily universal, two basic design systems should generally apply to all demodulator discriminators, those with detectors following the filters and those with amplifiers following.

What Responses to Use

It is recommended by Hoff[1] that three types of responses be used:

1. 850Hz shift, with 300Hz bandwidth channel filters.
2. 850Hz shift, with 85Hz bandwidth channel filters.
3. 170Hz shift, with 85Hz bandwidth channel filters.

The first listed response yields a discriminator output

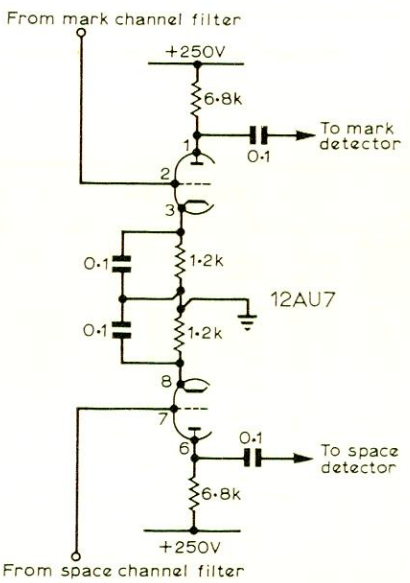


Fig 8.15. R—C coupled amplifier circuit.

which is linear with frequency, permitting one to copy a wide range of shifts by straddle-tuning the signal. The second response was recommended for limiterless copy of 850Hz shift. The third response provides a linear output for 170Hz shift. With a selection of these three responses available, one can copy all legal shifts satisfactorily by straddle-tuning, if sufficient gain exists in the stages ahead of the slicer.

Experience has shown, however, that overall better copy can be obtained from non-standard shifts by using "odd" shift discriminator designs rather than from straddle-tuning with a linear discriminator. Therefore, a unit having more selections and slightly different responses is suggested.

Each of the five positions is used for fm operation with the limiter on, and the last four are also used for limiterless copy, depending on reception conditions.

1. 1,100Hz shift, 330Hz bandwidth.
2. 850Hz shift, 140Hz bandwidth.
3. 700Hz shift, 125Hz bandwidth.
4. 425Hz shift, 100Hz bandwidth.
5. 170Hz shift, 75Hz bandwidth.

The first position may seem unnecessary but is included to enable copy of extra wide shift. If a fixed input bandpass filter for 850Hz shift was used, it would need to be bypassed for this position.

The remaining positions select responses for progressively narrower shifts, using progressively narrower bandwidths. **Fig 8.14** shows the measured responses of the five switch positions. The 170–75 and 850–140 responses are used probably 90 per cent of the time for general copy. Although the responses do not quite "overlap" at the 3dB points, the five selections enable copy of every shift ever encountered on the hf bands including some 85Hz shift signals, and test input signals with only 12 to 15Hz shift.

If the progressive shift discriminator switching scheme is used, it is probably not worthwhile to incorporate more than four discriminator responses in the legal shift range. Additional switch positions would yield only little improvement for the intermediate shifts which may on occasion be encountered.

General Designs

General designs are included here for four different demodulator systems. These are not offered as "universal"

TABLE 8.1

shift width	Band-width each filter	mark freq.	space freq.	R1	R2	R3	R4	R5
170	75	2,125	2,295	120kΩ	15	150kΩ	10	250kΩ
170	85	2,125	2,295	47kΩ	22	68kΩ	18	250kΩ
425	100	2,125	2,550	220kΩ	24	270kΩ	15	100kΩ
700	125	2,125	2,825	180kΩ	39	270kΩ	22	100kΩ
850	85	2,125	2,975	270kΩ	15	560kΩ	0	250kΩ
850	140	2,125	2,975	180kΩ	47	330kΩ	27	50kΩ
850	Linear	2,125	2,975	0	150	18kΩ	110	50kΩ
1,100	330	2,125	3,225	12kΩ	150	56kΩ	120	50kΩ

TABLE 8.2

mark freq.	space freq.	R1	R2	R3	R4	R5
1,275	1,445	22kΩ	24	39kΩ	20	50kΩ
1,275	1,445	0	30	8.2kΩ	24	50kΩ
1,275	1,700	18kΩ	39	47kΩ	30	50kΩ
1,275	1,975	18kΩ	47	82kΩ	33	50kΩ
1,275	2,125	68kΩ	27	240kΩ	15	50kΩ
1,275	2,125	8·2kΩ	56	68kΩ	39	50kΩ
*	*	—	—	—	—	—
†	†	—	—	—	—	—

Tables 8.1 and 8.2. General design values for Tailored Discriminator Responses, Detectors following.

TABLE 8.3

shift width	Band-width each filter	mark freq.	space freq.	R1	R2	R3	R4	R5
170	75	2,125	2,295	560kΩ	33	560kΩ	27	250kΩ
170	85	2,125	2,295	560kΩ	30	560kΩ	27	500kΩ
425	100	2,125	2,550	510kΩ	43	820kΩ	39	250kΩ
700	125	2,125	2,825	330kΩ	56	820kΩ	51	250kΩ
850	85	2,125	2,975	820kΩ	30	1·5mΩ	20	500kΩ
850	140	2,125	2,975	390kΩ	62	910kΩ	56	250kΩ
850	Linear	2,125	2,975	180kΩ	120	330kΩ	150	50kΩ
1,100	330	2,125	3,225	56kΩ	160	270kΩ	180	250kΩ

TABLE 8.4

mark freq.	space freq.	R1	R2	R3	R4	R5
1,275	1,445	100kΩ	43	150kΩ	39	50kΩ
1,275	1,445	56kΩ	51	100kΩ	47	50kΩ
1,275	1,700	47kΩ	47	220kΩ	47	250kΩ
1,275	1,975	27kΩ	56	300kΩ	56	250kΩ
1,275	2,125	120kΩ	33	750kΩ	30	250kΩ
1,275	2,125	91kΩ	68	390kΩ	68	50kΩ
1,275	2,125	0	160	56kΩ	180	50kΩ
†	†	—	—	—	—	—

Tables 8.3 and 8.4 General design values for Tailored Discriminator Responses, Amplifiers following.

(See text for wattage, tolerance, etc.)

* **Unsatisfactory operation for this shift range due to loss of sensitivity.**
† **Unsatisfactory operation in this shift range due to second harmonic of mark tone.**

designs, but should give excellent performance in most units seeing common use.

1. Detectors following 2,125–2,295–2,975Hz filters.
2. Detectors following 1,275–1,445–2,125Hz filters.
3. Amplifiers following 2,125–2,295–2,975Hz filters.
4. Amplifiers following 1,275–1,445–2,125Hz filters.

Values in **Tables 8.1–8.4** in connection with **Fig 8.14** present the various designs, 29 in all. A sufficient number of designs are given so the builder may select either the Hoff-recommended responses or the progressive shift sequence for his favoured audio frequency range and type of demodulator. Shift width and bandwidth data for **Tables 8.2** and **8.4** are included at the left of **Tables 8.1** and **8.3.**

The tables show resistor values only, in ohms. Resistors R2 and R4 should be 5 per cent tolerance; R1 and R3 may be 10 per cent. All fixed resistors may be $\frac{1}{4}$ or $\frac{1}{2}$W. Potentiometers (R5) are linear taper 2W. Values for C1 and C2 should be selected to resonate with 88mH toroids L1 and L2 respectively at the appropriate frequency. These capacitance values may be determined from the nomogram.

R1 and R3 provide isolation between each L—C filter and the drive point, and between the two filter elements themselves. R5 is used to balance the amplitude response of the mark and space frequencies, while R2 and R4 provide the equalized bandwidth responses.

In the amplifier-following designs, the voltage division factor is compatible with the TT/L units, and the reader may use that circuit if he wishes to add a transformer-coupled amplifier to another type of demodulator. In fact, the second, fifth and seventh designs of **Table 8.3** are taken directly from the TT/L circuit. If it is desired to add an R—C coupled amplifier, the circuitry of **Fig 8.15** is suggested.

In the detector-following designs, maximum voltage response consistent with adequate isolation from the driving point was the criterion, to avoid unnecessary loss of sensitivity at the slicer or trigger stage. In a given table, all designs will yield essentially equal amplitude outputs, so the amplitude outputs will be constant throughout the various switch positions of a response-selecting arrangement. Bandwidths in detector-following demodulators may vary slightly from the design values given here due to different loading characteristics, but these differences should normally be only minor, a few hertz or so.

It should be noted that with values of isolation resistance (R1 or R3 plus half of R5) below about 100kΩ, detuning of the L—C circuits may occur. This is more prevalent in the detector-following designs where the attempt was to yield minimum voltage division. Lowering of the resonant filter frequencies by 20 and 25Hz was noted in the worst cases.

The design values for R1, R3 and R5 are such that the potentiometer wiper arm should be very near the centre of its range for a balanced amplitude adjustment. Different value potentiometers than specified may be used if one-half the difference in value is added or subtracted (as appropriate) to each value of fixed resistance. Stated another way, the sum of the values of R1, R3 and R5 should be kept constant within a few per cent.

References

1. "High Performance RTTY Filters", Irvin M. Hoff, *QST*, August and September 1966; "Checking RTTY Shifts", Irvin M. Hoff, *QST*, May 1966; "Filters for RTTY", Jerry Hall, *RTTY Journal*, November 1968, December 1968, March 1969.

CHAPTER 9

TEST EQUIPMENT

MOTOR SPEED

MOST available teleprinter mechanical items rely on the accurate control of the speed of an electric motor. Both ac and dc motors are used, having a wide variation in voltage requirements. The initial inspection of any new machine should include the determination of the motor supply requirements, and the method of controlling the speed. If a synchronous motor is fitted, all the details will be stamped on the maker's label. As there is no means of adjusting the speed of a synchronous motor mechanically, the signalling speed of the machine will be determined by the frequency of the supply and the gearing fitted to the motor.

Should the machine be fitted with a governor controlled motor, the governor is adjustable over a relatively wide range of speeds, and it will often be found that 45 or 50 bauds may be catered for by readjustment. A few exceptions exist and caution must be observed at all times when making non-standard adjustments. It is not recommended for the governor of the Creed 75 machine to be changed from its designed operating speed.

Inspection of the motor governor will show a series of black and white markings on its cover, these being to enable the motor speed to be set or checked stroboscopically. The most common method of checking the motor speed is with the aid of a special tuning fork (strobe fork) with a shutter attached to the free end of the tines. The correct method of exciting a strobe fork is to strike one of the tines near its free end on the inside of the hand at the base of the thumb, in a direction in line with the other tine. The handle of the fork must be held firmly, keeping the grip well away from the root of the tines. *Never* strike the fork on a hard surface or it will be damaged beyond repair. When the fork is vibrating, the shutter will open and close twice for each complete cycle of the tuning fork tines, and the governor markings are viewed through the shutter. With the motor running and the governor illuminated with a strong light, the markings will appear stationary if the speed is correct. Should the marks appear to move in the same direction as the motor rotation, the speed is high and conversely if they move in the opposite direction the speed is low. Care must be taken to ensure that the marking appears exactly as though the governor were stationary, as it is possible to see a stationary display at other speeds than the correct one, although it should be immediately apparent by the unevenness of the markings.

Fig 9.1 illustrates typical strobe forks and **Table 9.1** gives the motor speed, number of governor markings and the frequency of the strobe fork that is required for correct motor speed adjustment.

TABLE 9.1

Motor speed rev/min	Number of governor spots	Frequency of strobe fork vibrations/s	Speed (bauds)	Typical machine types
3,000	5	125	50	Creed 7B, 8, 85R, 6S3, 54
2,727·2	11	125	45·45	Creed 7B, 8, 85R, 6S3, 54
1,500	10	125	50	Creed 6S5, 6S6
1,363·6	22	125	45·45	Creed 6S5, 6S6
4,200	4	140	45·45, 50, 75	Creed 75*
2,102	10	87·6	45·45	Various Teletype machines, eg 14, 15 and 19
2,308	10	96·19	50	Various Teletype machines, eg 14, 15 and 19
1,800	35	87·6	45·45	Teletype typing reperforator FPR.21G B226, FPR21 GB22, FPR23 GB226 and FPR23 GB222

*It is recommended that the motor speed of the Creed 75 is maintained at 4,200rev/min.
Note: The official method of changing speed is by changing the gear ratios but the table shows alternatives that will ensure satisfactory operation.

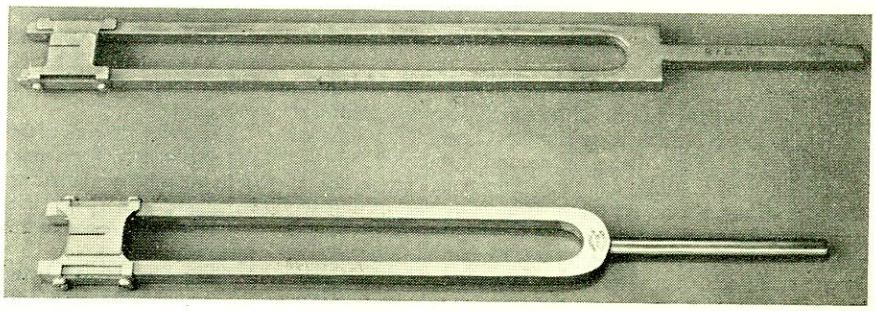


Fig 9.1. Typical strobe forks. The upper fork is a Teletype Corporation's and is marked 87·6 VPS (vibrations per second). The lower one operates at 125Hz and is a standard GPO item for Creed model 7 machines.

Another common method is to use a stroboscopic light source, and provided the frequency of operation is known accurately the motor may be set to any desired speed within its operating range of adjustment. Some "Teletype" machines are fitted with a small ac driven neon lamp close to the governor markings, and provided the governor is viewed in subdued ambient lighting a clear indication is shown of the motor speed. This assumes that the correct speed will be indicated by the mains supply available.

Some teleprinter test sets are equipped with a high stability oscillator capable of driving a small neon lamp mounted in a torch like holder. These are, however, usually set for one particular speed only.

Should no test equipment be available, a rough check on the motor speed may be obtained in the following manner, provided the machine is fitted with transmitting contacts.

Carefully determine the speed ratio between the motor shaft and the camshaft of the transmitter by counting the number of gear teeth. Arrange for the machine to transmit the "letter shift" or "all space" code continuously by holding the transmitter abutment free. Under these conditions the transmitter contacts will open and close or change over, depending on the type of machine, once every revolution of the transmitting cam. If an electromechanical counter, switch and suitable power supply are wired in series with the transmitter contacts, the counter will operate once for each revolution of the camshaft. By counting the number of revolutions in a predetermined time the motor speed can be calculated. The longer the period of time, the more accurate the determination of the motor speed.

MEASURING SHIFT

The easiest and most accurate method of shift measurement is with the aid of a digital frequency meter. As the upper frequencies used in generation of fsk with the conventional ssb transmitter or transceiver are limited to the order of 3 kHz and the accuracy requirements as to actual frequency are not too stringent, a relatively simple meter may be constructed using TTL integrated circuits to the designs as published from time to time in the amateur radio magazines. Provided the frequency meter is only required for af measurements, the mains supply frequency may be used as the frequency standard and hence a reduction in component cost. Signal gating times should be at least 1s.

For further economy, a two-digit display with switchable gating times of $\frac{1}{10}$s and 1s would enable frequencies below 9,999Hz to be measured to within an accuracy of the percentage mains frequency deviation $\pm$1Hz. The $\frac{1}{10}$s gating time will indicate the thousands and hundreds, and the one second gate tens and units.

An alternative to the digital frequency meter is a simple analogue meter as described below. The circuit is shown in **Fig 9.2**.

Two small 1·5V batteries provide the bias for the input clipping diodes. The output of the clipper drives a grounded emitter amplifier which also supplies a small amount of limiting. This stage drives a second grounded emitter limiter through capacity coupling. The signal amplitude at the base of the second transistor is large enough to cut the collector current off and into saturation, producing volts to charge capacitor C from the collector resistor R. This voltage at cut-off approaches the supply voltage less a small drop through R. Under saturation conditions the voltage drops almost to zero and C discharges through the series diode. The time constant of the meter is fairly long and hence integrates the charging pulse on C and gives a steady meter reading.

To expand the meter scale over the 2,000 to 3,000Hz range, the second battery B2 is used. This has the effect of suppressing the reading until the input frequency exceeds approximately 1,600Hz.

It should be noted that the meter deflection is dependent upon the main battery B1 voltage. It is recommended that a voltage of about 8·5V be used, and then, as the battery deteriorates, the voltage may be adjusted by means of the series variable resistor. Provision is made to check the battery by means of the CAL/OPR switch, and the meter scale should be marked with a red line to which the needle should be set before carrying out any measurement.

Initial calibration may be carried out using a standard signal generator, etc, or using the tuning fork standard described in this chapter.

The most useful accessory to the amateur rtty station is the crt shift monitor. It makes the tuning of rtty signals as simple as tuning ssb. An added advantage is that the effects of selective fading can be seen at a glance and corrective measures taken if necessary. If a sufficiently large diameter cathode ray tube is utilized, direct measurements of shift may be taken from the face of this crt. However, tubes below about 3in diameter are very useful for tuning purposes but the angular position of the trace will not be sufficiently well defined for frequency measurements of any accuracy.

As with any analogue frequency indicating device, its usefulness is only as good as the initial calibration and regular checking, for which purpose a digital frequency meter should be built or borrowed, or alternatively a signal source of high accuracy at the particular frequencies being used.

RTTY SHIFT MONITOR

Present amateur rtty practice requires that the receiving station should be able to tune in an rtty signal accurately on the receiver with the minimum of delay. The X monitor to be described enables the operator to do these two things with ease.

Displacement of the mark and space signals is obtained by means of a simple phase-shift network to give an X pattern whose two legs are composed of the mark and space signals. Not only can the shift be read directly from the crt display, but total signal mistuning is also seen and can be swiftly corrected.

The valves used are all EF86, triode corrected, and the crt may be a VCR97 or similar. The circuit is shown in **Fig 9.3**.

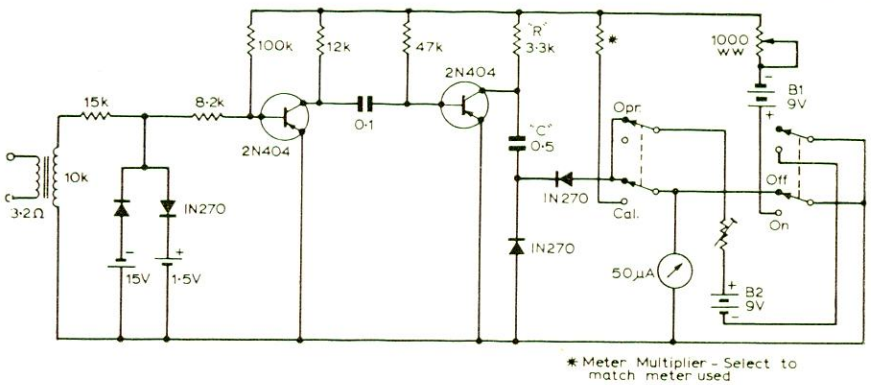
The heart of the device is the phase-shift network consisting of a capacitor of 7,500pF and an inductor of 500mH. The Q of the inductor is reasonably important and in this case a *Mullard* Vinkor inductor wound for the value shown was used.

The series network of 0·05μF and 130mH is used to equalize the response between mark and space. This is in conjunction with the potentiometric network in the grid of V3, which can be adjusted on test for the best response.

Connection to the terminal unit is made after the bandpass filter at the input.

Calibration is performed by feeding in an af source of 2,125 and 2,975Hz and using a felt tip pen to mark the crt

Fig 9.2. A simple analogue frequency meter.



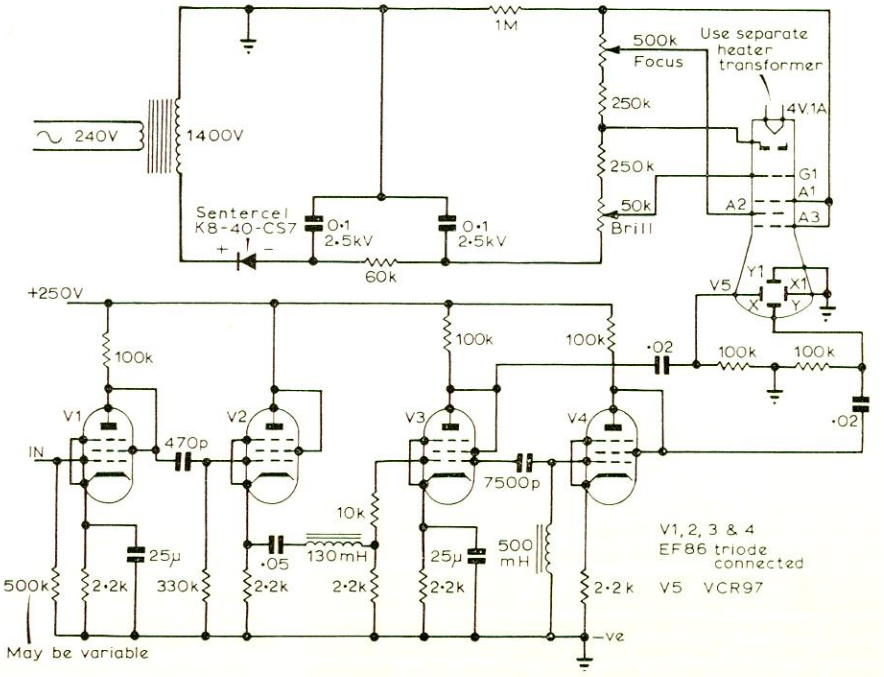


Fig 9.3. The circuit diagram of a rtty shift monitor.

face directly. It will be found useful also to mark the trace for 2,550Hz, as this will provide a datum for other shifts such as 170Hz.

In use, it is only necessary to align the crt display with the marks on the tube face by means of the receiver tuning and to turn on the printer, **Fig 9.4**. Not only is the shift of the incoming signal shown instantly, but the correct tuning point also. The angle between the arms of the X gives the shift, while the whole display rotates on the tube face according to the correctness of tuning. At the same time, one can instantly detect from the position of the mark signal whether the station is being received "the right way up" or "upside down".

It is useful as well in giving an indication of selective fading of one signal relative to the other.

TRANSISTORIZED PHASE-SHIFT RTTY SCOPE

A cross-pattern scope or the ST-5 and ST-6 type tuning meter is fine for tuning normal rtty signals; however, during QRM conditions a phase shift type scope is preferable to help sort out the proper mark-space frequencies. This phase shift monitor scope uses signals directly from the receiver output (or tu input) and displays a rotating line on the face of the crt. The angle of rotation is a measure of frequency, while the length of trace indicates amplitude; thus, most of the crt face area contains useful spectrum information. At a glance one can determine approximate frequency shift of either the received or transmitted frequency, can tune the signal rapidly to correspond to the tu filters, and can determine frequency separation of interfering signals.

Theory of Operation

The heart of the phase shift indicator is the simple RLC network shown in **Fig 9.5**. The series LC circuit is resonant near the mid-frequency of interest. Near resonance, the impedance of the LC circuit is minimum; thus, E_T approaches zero while EL is large and exhibits rapidly changing phase about the resonant frequency. Two sine waves applied to the deflection plates of a crt produce a pattern dependent upon the phase and amplitude relationship between these sine waves. With the two sine waves either in phase or 180 degrees out of phase, a straight line appears whose angle on the crt face depends upon the relative amplitudes of the two signals. With 90 degrees phase shift between the two deflection plates, an ellipse appears with an eccentricity dependent upon the relative amplitudes between the two signals.

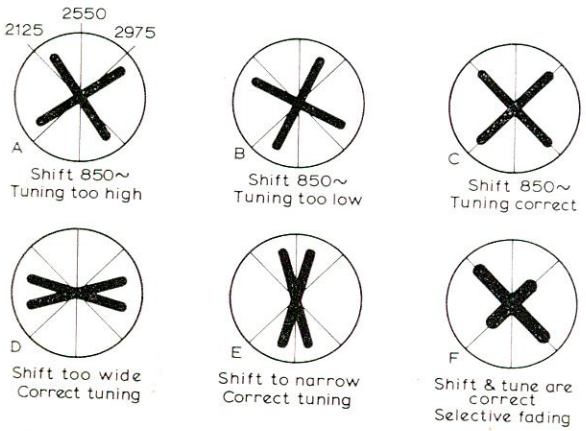


Fig 9.4. Typical patterns and their meanings as displayed on the shift monitor screen.

Referring to **Fig 9.5** the LC circuit is resonant near the centre of the frequency range of interest (2,550Hz). For a high Q circuit, the phase angle varies from near 180 degrees to 0 degrees over a narrow range of frequency, which yields straight lines on the oscilloscope tube. Around resonance, an ellipse appears since the signals are around 90 degrees out of phase; however, the width of the ellipse is collapsed to zero since the amplitude of the series voltage (E_T) decreases as the phase approaches 90 degrees. Thus a straight line will appear on the crt for all frequencies of interest and will rotate about the centre of the tube face as the frequency varies. Typical pattern for a complete phase shift monitor scope receiving rtty signals appears in **Fig 9.6**.

Circuit Description

The complete schematic appears in **Fig 9.7**. The input stage (TR1) yields a gain of about 20 (approximately the ratio R4/R5). R2 and R3 are bias resistors. TR2 is an isolation emitter follower which reduces TR1 collector loading and offers the current drive necessary for the LC phase shift network. The series compensating network (C2, L1, R8) could be eliminated; however, it offers two advantages. C2-L1 resonate of approximately 2kHz to yield an increasing impedance over the 2–3kHz indication range which compensates for the increasing voltage across the phase shift inductor (L2) with increasing frequency. This maintains the same scope trace length at 2,125Hz and 2,975Hz. Another advantage of C2-L1 is that signals far above and below the 2–3kHz range do not produce a trace on the crt, thus limiting the pattern to the desired range of frequencies; R9, C3, L2 comprise a phase shift network described in **Fig 9.5**. C3-L2 resonate at 2,550Hz. TR3 serves as an isolating emitter follower to offer a high impedance across L2 and maintain high TR for the network. TR4 and TR5 are identical amplifier stages with a gain of approximately 20 (ratio of collector load to emitter resistor). Resistors R14–R16 and R18–R19 furnish bias for the transistors.

Almost any small crt can be used such as the 2BP1, 2AP1, 3BP1, 3AP1 and 3RP1. This circuit has adequate output swing to drive any of them with the supply voltages used in this circuit since the crt deflection factor is greater with reduced accelerating potential (usually 1,000–1,500V). All are sufficiently bright for a well lighted shack. Caution: check pin connections and heater requirements for your tube (3AP1 requires 2·5V). Don't worry about the spot that finally burns on the centre of the tube face during undeflected periods; no useful information is contained in the centre of the tube anyway. Centring controls are dispensed with for simplicity. Most CRTs are fairly well centred as is: however, a small magnet can be glued to the crt neck for centring if desired. A chip from a small magnet is adequate; just slide it around the tube neck until the display is centred on the tube face and a spot of epoxy will hold it.

Initial Adjustment

At first turn-on, defocus the spot until after the centring magnet is glued on. With power applied and the input sensitivity control (R1) turned down, the following dc voltages should exist:

TR collector—approximately half of the negative supply voltage.
TR2 emitter—within 1V of TR1 collector.
TR3 emitter— −0·5 to −1·0V.
TR4 and TR5 collector—approximately half the positive supply voltage.

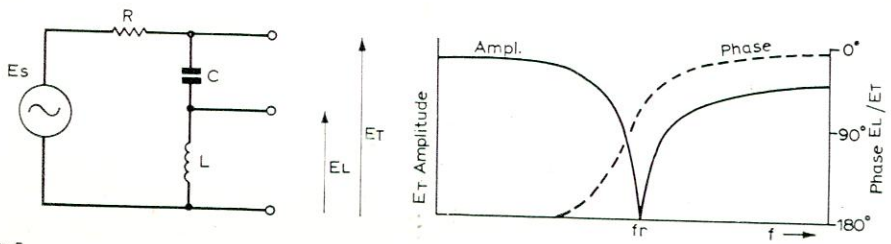


Fig 9.5. RLC phase shift network.

If the readings are off more than 20 per cent, adjust the operating points by changing the value of R2, R14, R18. Increasing R2 reduces the (negative) voltage of TR1 collector and TR2 emitter. Increasing R14 increases TR4 collector voltage, increasing R18 increases TR5 collector voltage.

Apply a 2–3kHz sine wave at the input. A straight line should appear on the scope; adjust the amplitude for $\frac{3}{4}$ screen deflection. Focus the spot with R24. As the frequency is varied, the line should rotate about the centre. If you prefer rotation in the other direction reverse the deflection plate connections (pins 6 and 7) at the crt (or equivalent pins for your crt). The line should rotate smoothly from 2–3kHz, with reduced angular rotation and shrinking in size below 1kHz and above 4kHz. Calibration marks are placed on the face of the tube by stretching fine black threads across the tube face (behind the bezel) and adjusting these over the trace at desired frequencies (2,125, 2,295, 2,975Hz). A spot of glue out of sight at the tube edge will hold the threads in place. If available, a calibrated oscillator or an oscillator and counter may be used for calibration. However, for those using the ST-5 or ST-6 demodulator, the calibration threads can be easily placed right on the filter frequencies. Just connect the monitor scope to the receiver output, turn on the calibrator and bfo and tune for a tone. Tune the bfo for maximum on the tu tuning meter (or maximum measured discriminator test point voltage), and repeat for mark and space on the narrow and wide shift positions of the tu. Adjust the calibration threads over the scope pattern when the peak discriminator output is obtained.

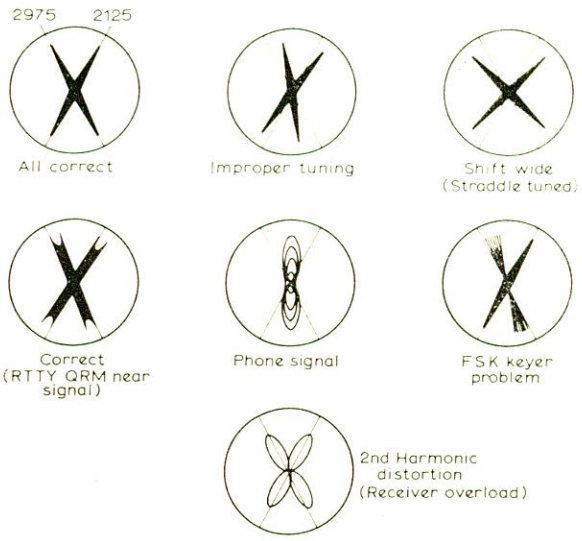


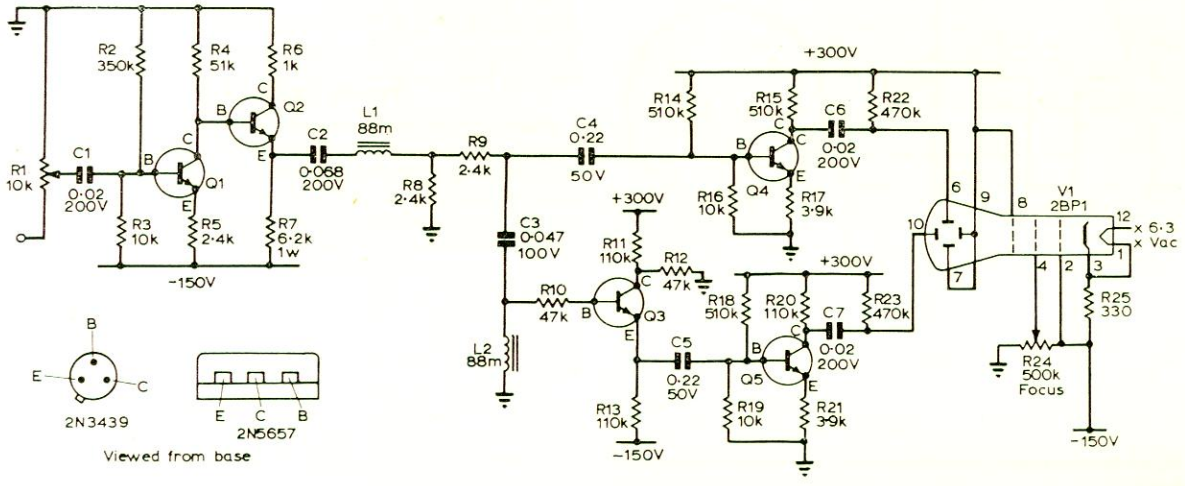
Fig 9.6. Phase shift scope patterns. For clarity only wide shift is illustrated.

INDICATOR (CRT) TYPE 3 (10Q/16156) (AP67980A)

This unit is a visual indicator for the correct tuning of fsk signals, and for the comparison of signals from different aerials in diversity reception. It is most commonly used in conjunction with the FSR or FSY series of terminal units, which provide access to the discriminator output for driving the indicator. Polar and af signals may be monitored from two independent terminal units, the selection being by means of a front panel switch. The display, when monitoring the af signals, is as a conventional oscilloscope, with the timebase variable over the range 3–25Hz. Polar signals are shown in the form of a V with the timebase amplitude determined internally at a frequency of approximately 5kHz. The right-hand arm of the V indicates the amplitude of the negative signal from the discriminator, and the left-hand arm the positive signal. If the terminal unit is receiving traffic, the V pattern will indicate tuning accuracy; any difference in height indicating incorrect tuning. Position 3 of the function switch is provided for the initial setting of the V balance control.

To appreciate the significance of the display, a good clear signal should be tuned in, and its general character observed. This signal will produce a solid figure of even illumination, with a slightly brighter bar at the top of each arm. When tuning a weak signal with heavy background noise, bars of brighter fluorescence will show across the V. During the

Fig 9.7. Complete circuit diagram of phase shift monitor scope.



tuning process, it is possible to produce false Vs. These can be formed by the interference signal beating with one of the shift frequencies, or they may be caused by two entirely separate adjacent transmissions. The false Vs are not easy to identify, but usually the arms are taller, thinner, and less solid in appearance than the correct **V**. **Fig 9.8** shows examples of V presentation relative to the polar input.

In the positions marked slow and fast external, facilities are available for use of the indicator as a conventional oscilloscope. The timebase range is 30–200Hz and 250–1,800 Hz respectively, and the Y amplifier input circuit is switched to the front panel terminals.

Details of the power and signal connections are shown in **Fig 9.9**. The ac power supply may be either 105–125V or 210–250V at 50/60Hz. The mains transformer primary is wound in two sections, and must be parallel connected for 110V operation and in series for 240V supplies. The terminal board of the mains transformer, located behind PL3, has the various tapping points for voltage selection.

In position 1 or 2 of the function switch, the appropriate discriminator output is applied to V1a grid, via the **V** gain control, and a low pass rc filter network to remove residual af carrier frequencies. V1 is a double-triode paraphase amplifier giving a push-pull output at the two anodes, the two halves being balanced by means of the **V** balance potentiometer. The push-pull output from the anodes of V1 are applied to a double diode gating circuit (V3) and capacity coupled to the crt Y1, Y2 deflection plates. At the same time, the output from V1a is applied to the X1 deflection plate.

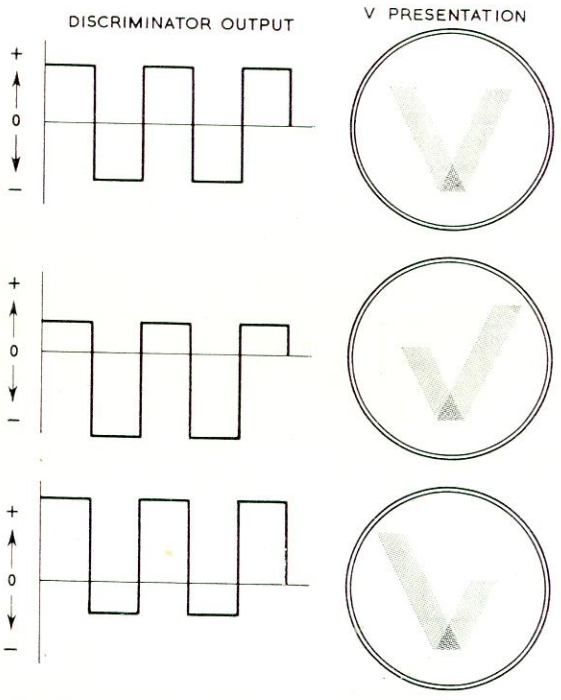


Fig 9.8. Indicator (crt) type 3, V presentations relative to polar input.

The 5kHz timebase waveform is coupled to deflection plate X2. **Fig 9.10** is a simplified circuit of the crt plate connections for **V** presentation. The timebase amplitude control sets the width of the **V** trace and also the trace length in the waveform monitoring positions of the function switch. Capacitor switching in the timebase oscillator (V4) controls the ratio of trace length between **V** and waveform monitoring. All preset controls are mounted behind masking for setting up the crt operating conditions, together with the sync level and timebase amplitude potentiometers.

Positions 4 and 5 of the function switch are provided for pre-wired inputs to the rear of the indicator for viewing the af input to the terminal unit.

The input sensitivity of the monitor may be checked as follows:

1·3V rms input to pin 1 of PL1 (pin 4 earthy) the function switch at position 1, **V** gain control at maximum and **V** balance adjusted for a symmetrical trace; the **V** should be 1in high. The input signal may be derived from any low-voltage mains transformer and potentiometer.

0·5V rms at 3kHz to pin 3 of PL1 (pin 4 earthy) the function switch at position 4, input gain control at maximum; the height of the trace should be 1in. The same sensitivity should be obtained in positions 6 and 7 with the input applied to the front panel terminals.

Plug Connections

PL1 and PL2	PL3
Pin No. 1 Polar input	Pin No. 13 ac supply
Pin No. 2 —	Pin No. 14 ac supply
Pin No. 3 af input	Pin No. 15 —
Pin No. 4 earth	Pin No. 16 earth

Valve types		
V1	CV1985	6SL7GT
V2	CV1985	6SL7GT
V3	CV1930 or CV1931	6H6GT
V4	CV1985	6SL7GT
V5 (crt)	CV279	E4205/8/7
V6	CV574	6X5GT
V7	CV574	6X5GT

Should a terminal unit be available with a linear discriminator preceded by a limiter, the discriminator output may be calibrated in terms of voltage proportional to frequency, and this means used to measure the frequency of steady tones. Care will have to be taken in using this method to prevent loading the discriminator output and upsetting the normal functions of the terminal unit.

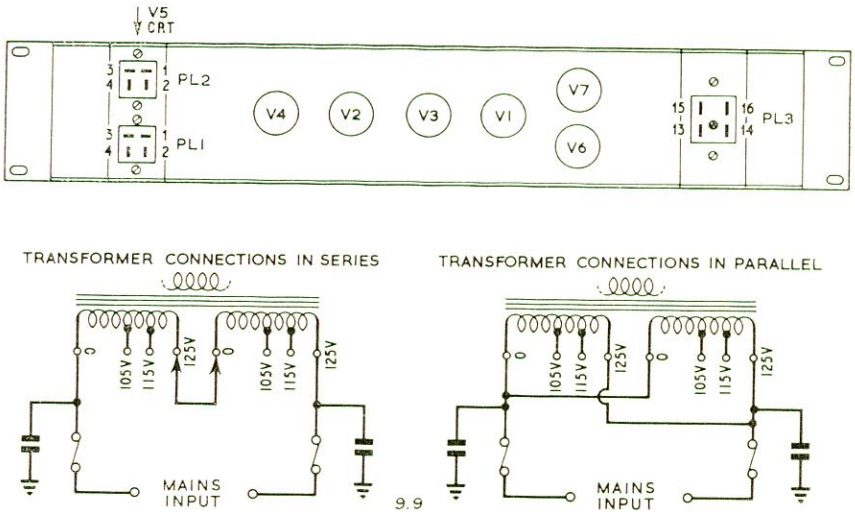
TONE STANDARDS

Two methods are commonly available for generating afsk tones: quartz crystal oscillators followed by a dividing circuit to produce the audio tones, and a tuning fork oscillator at some submultiple of the required frequencies.

With the introduction of digital integrated circuits at reasonable prices over the last few years, the use of quartz crystal oscillators has become a more attractive proposition as a source of accurate frequencies, and it is possible that various designs will be evolved from time to time. Reference should be made to manufacturers' data sheets and application notes for ideas on the design of frequency dividers.

The tuning fork oscillator described in some detail below may form the basis of a suitable amateur tone standard. When using the 425Hz fork, the fifth, sixth and seventh harmonics may be used to excite tuned circuits of 2,125,

Fig 9.9. Power and signal connections for indicator (crt) type 3.



2,550 and 2,975Hz respectively, covering all requirements for 850 shifts. If the fork frequency is reduced to 85Hz, reference frequencies at the twenty-fifth, twenty-sixth, twenty-seventh, thirtieth and thirty-fifth harmonics corresponding to 2,125, 2,210, 2,295, 2,550 and 2,975Hz could be produced, although intermediate amplifiers will be required hence increasing the complexity of the standard. A unit of this standard would be indispensable in the rtty station and is well worth considering as it would give mark, space and centre frequencies for shifts of 850 and 170Hz.

The circuit consists of a single transistor tuning fork sustained oscillator and is shown in **Fig 9.11**. The tuning fork is a 425Hz item, available from the usual rtty component supply houses, but musical tuning forks may be modified for this frequency. If a 440Hz fork is available it may be lowered in frequency by filing the base of the U and so effectively lengthening the tines. If too much metal is removed, the frequency may be raised by shortening the tines by filing the ends equally. The handle of the fork should be threaded and securely mounted in a solid metal block which in turn is mounted firmly on the base. The minimum thickness of the mounting block should be $\frac{1}{4}$in and that of the base $\frac{1}{8}$in. An absolutely solid assembly is essential for best results. Steel should not be used.

The magnetic circuit is made up of a small permanent magnet, two exciting coils and the means of holding the magnet, and its purpose is to provide bias for the fork. The coils may be obtained from an old pair of headphones or from unwanted relays, and should be of about 1,000Ω dc resistance. Lower resistance coils will work but will cause the circuit to draw more current. The supports for the coils and the magnet must be made of iron or steel, and old PO 3000 series relay frames make excellent units when cut down. The method of assembly is shown in the photographs. If the magnet is not long enough to fit between the supports when the coils are fitted, it may be lengthened by inserting steel spacers between it and the supports, but care must be taken to make sure that the whole assembly is clamped up tight.

The air gap between the fork tines and the exciting coils should be about $\frac{1}{64}$in, but if lower resistance coils are used, the spacing may be increased. This is because the lower resistance coils allow more current to be drawn, the attraction is thus greater, resulting in an increased amplitude of fork vibration. If under these conditions the gap is small, the tines will touch the pole pieces.

The output, at 425Hz, may be taken from the collector of the transistor via a capacitor, or from a separate pickup coil. The fifth and seventh harmonics at 2,125 and 2,975Hz may be selected by means of suitable filters (see chapter 8).

POLAR RELAY TEST SETS AND ADJUSTMENTS

To achieve maximum stability and efficient performance of a relay with varying levels of energization, it is essential

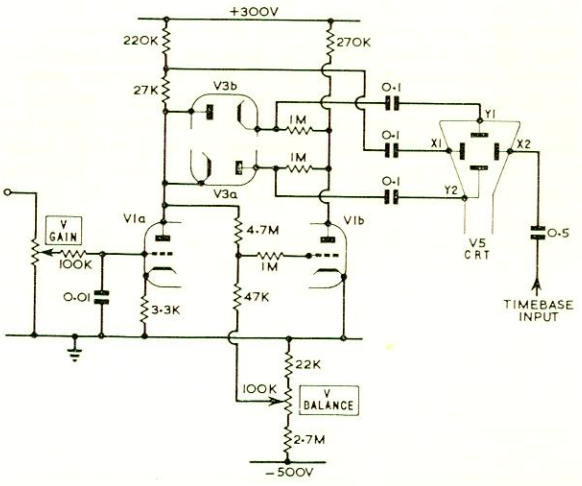


Fig 9.10. Simplified circuit of crt plate connections for V presentation.

that the armature movement be symmetrical relative to the centre of the pole-piece gaps.

The two methods of testing and adjustment employed for the various versions of polar relays are an initial dc followed by an ac adjustment.

All the information possible should be gathered for the particular relay being adjusted and the details may be used as given in chapter 6. Should no information be available, an educated guess will have to be used and the discussion of polarized relays in chapter 6 may be useful in this respect.

The most commonly used type of relay in telegraph circuits is the each side stable version; others may be obtainable but have limited use in the amateur station and will not be considered.

The first operation with any relay is to remove the cover and check its type and the condition of the contacts. If maintenance is required, refer to chapter 6 for details. Should the overall condition seem satisfactory on visual inspection, and the relay is of the one side stable type, set the position of any bias magnet in the mid position, eg Carpenter Type 3. Move the armature from contact to contact very gently with a non-magnetic probe such as a piece of stiff copper wire, when it should remain on the contact towards which it was moved. If the forces required are dissimilar as detected by the hand movement, loosen the contact locking screws or clamps and adjust the contact on which the load is greatest towards the armature a small amount and move the opposite contact away from the armature a similar amount. Most relay contact screws have markings on their periphery and these should be utilized for equal adjustment. The gap between the armature and free contact must be approximately 5 mil. Although this will vary between relay types, it will be a good all-round figure for relays used up to a signalling speed of 75 bauds. If the gap or total travel of the armature is greater than this, both side contact screws must be moved towards the armature the same amount and if less, away, until the above conditions are met. If a relay contact spring balance is available, and the relevant data, the actual contact force may be measured at this point and a decision taken as to what is to be done to correct any fault in this aspect. If the forces are too great the side contacts will have to be moved closer together and if too small farther apart; this will change the armature travel and also the contact transit time and often a compromise will have to be made. The tendency should be towards correct armature travel. If the contact adjustment appears to be varying intermittently it is possible that a particle of magnetic material has attached itself to the magnet pole face and is operating as a shunt between the magnet and armature. If this is so, the magnet must be carefully removed, cleaned with adhesive tape and replaced in the correct position.

Reference should be made to chapter 6 on the repair of this relay and the general requirements for assembly.

Set up the dc test circuit as shown in **Fig 9.12** and measure the "just operate" currents for relay change-over. These currents should be equal to within about 5 per cent. If unequal, move the side contacts a very small amount and relock the contact screws. Both contacts must be moved each time adjustment is done to maintain the contact gap and, with care, very fine adjustments may be undertaken.

When satisfied that the contacts are in the correct position, increase the coil current to its working value and operate the relay electrically several times, and recheck the armature

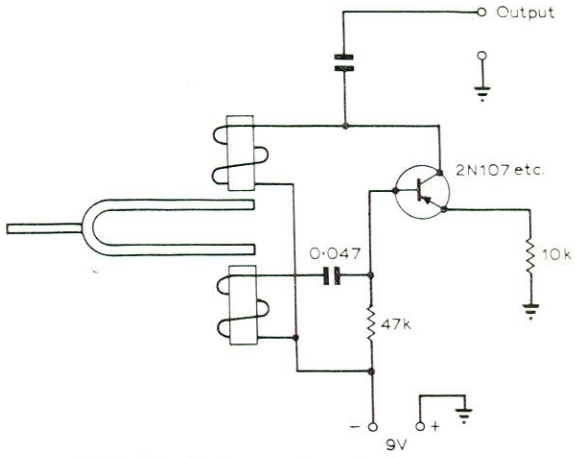
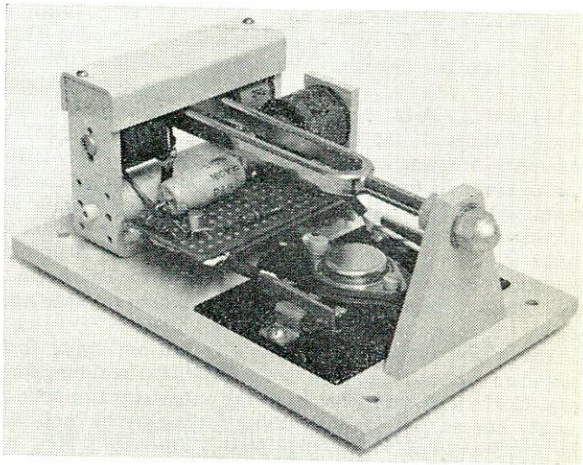
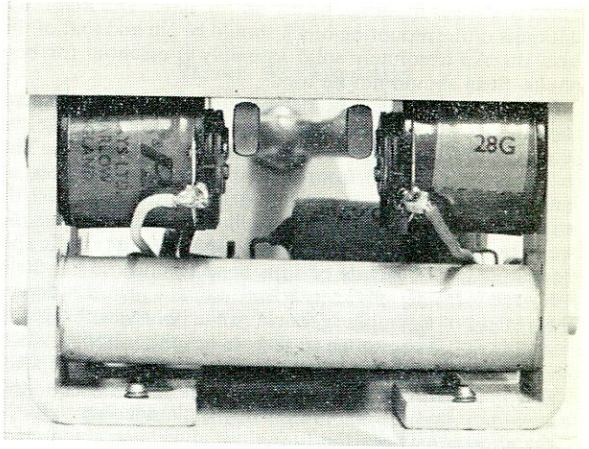


Fig 9.11. Circuit diagram of a tuning fork oscillator.



Above: **a tuning fork frequency standard using the single-transistor circuit of Fig 9.11.**

Below: **end view of the tuning fork, showing the two coils and the bar magnet.**



movement at the "just operate" current levels once again. If after two or three checks it is found that the relay will not hold its adjustment, it is possible that the armature mounting has been damaged and the relay should be repaired or replaced. One corrective action that may be undertaken is to increase this armature travel a small amount by moving both side contact screws away from the armature, but this will decrease the relay sensitivity and maximum operating speed. If this can be tolerated the relay may be salvaged. An upper limit of armature travel must be considered to be about one and a half times the normal travel for reliable operation.

The ac Method of Polar Relay Adjustment

This method should be employed for the final adjustment of relays when a perfectly symmetrical ac performance is essential.

It must be realized, however, that the ac method is insufficient in itself to provide a satisfactory setting up of the relay since it does not guarantee coincidence in the zero position of mechanical and magnetic forces; the dc method must, therefore, always be used to give the initial adjustments after repair or major maintenance. The ac method is used solely to compensate for minor differences which may exist in the compliance of the side contact springs, and to provide a simple means of obtaining the correct adjustments after contact cleaning and burnishing. A polar relay ac test set is shown in **Fig 9.13**. In this circuit the percentage contact time may be read directly in terms of full-scale deflection on meter M1 and the percentage bias on meter M2.

M1 is an 0–10mA moving coil meter, the scale of which may be graduated 0–100 divisions. M2, incorporating its series resistor R5, is a voltmeter of 10,000Ω reading 10–0–10V. For ease of reading it may be provided with a scale graduated 100–0–100 divisions. R1 and R2 are 1,250Ω wire wound, non-inductive resistors matched to 0·1 per cent, of negligible temperature coefficient and capable of carrying a current of 10mA continuously. The resistors R3 and R4 are of such values and R4 is of such a type as to make it easy to adjust meter M1 to reach full scale when the relay armature contact is stationary on either side contact. Under these conditions M2 will indicate full scale on either side according to the contact on which the armature is resting.

The source of dc to the test circuit should be from a battery of not less than 12V. M3 is an 0–10mA ac meter of a type which will not seriously distort the supply waveform. The ac supply should be substantially free from even multiple harmonic distortion since these may cause the bias meter M2 to read incorrectly. The sum of the impedances M3 and R6 and that of the source should preferably be of the same order of magnitude as the impedance from which the relay will normally be operated.

A typical supply circuit for the input to the relay, preferably using the ac mains supply as a test source, is also shown in **Fig 9.13**.

With new contacts or with contacts that have just been burnished, there frequently exists a surface film of foreign matter which prevents satisfactory contact being obtained. This film can usually be removed by passing a current of approximately 100mA through the contacts for about 5s while the relay is vibrating. For this purpose, the non-locking push switch A1 and A2 is provided to enable the relay contacts to be momentarily connected to the battery through resistor R7, the latter being chosen to pass approximately 100mA. If an air cored inductance of 100mH is inserted in the battery lead, slight sparking will further assist the removal of surface film.

In the construction of the ac test set, special precautions must be taken to prevent the magnetic field of the meters

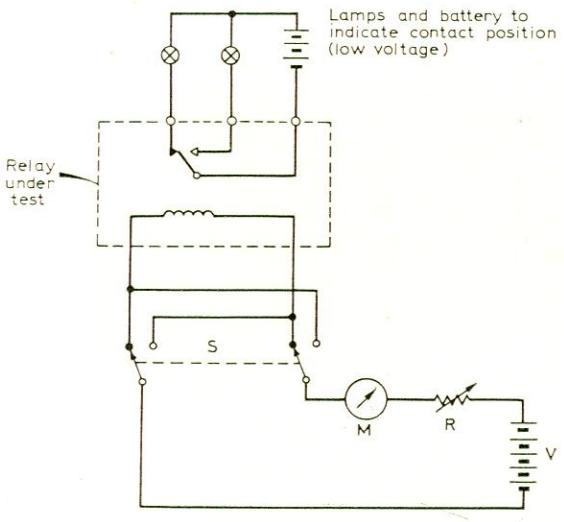


Fig 9.12. Polar relay dc test circuit.

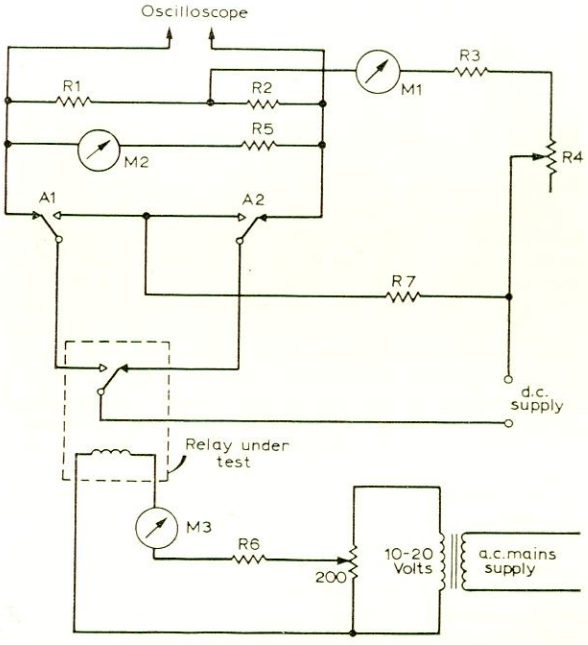


Fig 9.13. Polar relay ac test circuit.

from influencing the performance of the relays under test.

The following procedure should be adopted:

(*a*) Remove the relay cover.

(*b*) Examine the relay in good lighting to ascertain there are no metallic particles of dust in evidence between the pole pieces and armature.

(*c*) Set the bias magnet if fitted to its mid-position.

(*d*) Connect the ac test circuit supply to the relay winding and adjust the emergization to the relevant value. The current will be indicated on meter M3. If the current requirement is now known set the rms current equal to twice that obtained during the dc tests for a condition of just operating.

(*e*) If the relay is in good order it will operate on this ac energization, with its percentage contact time indicated on meter M1 and its bias on M2. If, however, the relay is out of adjustment or not operating, meter M1 will indicate full-scale deflection and meter M2 will record 100 per cent bias. If both contacts are making, meter M2 will indicate zero bias. Should this be the relay must be set up in the dc test circuit and readjusted.

(*f*) If the operating performance is inconsistent and the bias is found to be varying greatly, it will generally be caused by incorrect clamping of the contact mounting. During these tests it is advisable to connect the relay contacts to the input of a suitable oscilloscope so that the contact pattern may be observed. Contact bounce will be shown by one or more breaks in the trace obtained from either side contact and can be eliminated by cleaning and adjustment.

(*g*) The side contacts must be finally adjusted to give zero bias condition and the correct percentage contact time as specified in the data. A typical contact time of 80–85 per cent should be aimed for.

(*h*) Check that the side contact locking screws are tight and replace the cover and recheck the relay operation.

(*i*) If the relay is fitted with a bias magnet adjustable from outside the cover, make a final bias adjustment when the cover is in place.

TDMS (TELEGRAPH DISTORTION MEASURING SETS)

Strobe Types

Various types of telegraph distortion measuring sets have been manufactured utilizing the strobe principle. This system of measurement relies on the accurate speed control of an electric motor to rotate a neon lamp round the periphery of a disc either once for each character or once for each element. The neon lamp is flashed for each signal transition from mark to space and space to mark, and it will be seen that the angular position of the neon at the time of flashing is proportional to the time of the telegraph signal change of state. This type of TDMS is often rather large physically and must be viewed in subdued lighting to obtain a clear indication. It also has another disadvantage in that the start of the telegraph signals may appear anywhere on the disc circumference as the neon lamp is continuously rotating, and unless the input signals are at cadence speed it will be impossible to read any deviation or distortion from the scale on the disc. The usefulness of the strobe TDMS is also limited to the availability of interchangeable discs or scales to unit 7, 7·42, 7·5 and 8 unit codes, and the ability to check and maintain the motor speed within very close limits.

The strobe type TDMS has almost been wholly replaced by the crt type where the reference or beginning of the start pulse always occurs in the same position, irrespective of the number of units in the character, and any speed control or change is done electronically.

TDMS5

The telegraph distortion measuring sets known as the TDMS5 or Type 14011 (10S/17122) or 14011A (10S/17138) are electronic instruments for generating telegraph signals and for monitoring these signals (or received signals) by means of a 2·75in cathode-ray tube.

The instrument provides a selection of accurately derived dc telegraph signals for setting up routine servicing and fault location in telegraph equipment. There is also provision for the rapid checking and adjustment of telegraph relays and limited facilities for shunt monitoring and checking of double-current (polar) telegraph signals for speed and distortion.

The following types of test signals are provided:

1. Alternative mark and space signals, continuously following each other. These are known as 1.1 reversal signals.
2. Alternating pairs of mark and space signals, known as 2.2 reversal signals.
3. A steady mark signal.
4. A steady space signal.
5. Any teleprinter character, as determined by the setting of the five unit keys on the front panel. This character will be continuously repeated.
6. A 100 character test message.

All these signals can be transmitted as perfect (less than 1 per cent distortion), or given any predetermined start-element distortion up to 50 per cent. The amount of distortion is continuously variable and can be monitored on the crt.

The test signals may be either 7, 7½ or 8 unit code and can be transmitted on any one of the nominal speeds according to the speed selection switch.

There is a control fitted with a calibrated dial and varies the speed 10 bauds either side of the nominal speed set by the range switch.

The following tests can be made on relays:

1. Adjustment of bias. The relay can be adjusted for neutrality while the instrument is operating and the effects of the adjustments can be observed.
2. Measure transit time.
3. Measure contact time.
4. Check for contact bounce.

When monitoring input signals the normal operation of the transmitting circuits is unaffected. Thus the incoming signals can originate either from an external source or from the output terminals of the instrument, since changing the display switch from "normal output" to "input" does not cut off the output terminals, it only changes the signal displayed from those leaving the instrument to those coming into the instrument. It is thus possible to send a pure signal into a piece of equipment and monitor the output from that equipment to check if any distortion has occurred. Immediate comparison can be made at any time between the output and input signals.

The output circuit of the TDMS5 is in the form of relay contacts fitted with contact protection components, and

external voltages must be applied to the relay contacts as required. The normal relay is a Carpenter Type 3 and this is a plug-in unit fitted inside the instrument. It may be removed and installed in the socket on the front panel for checking purposes without effecting the operation of the relay checking facility.

The crt display is in the form of circular trace, the time taken for one sweep being equal to the duration of one character-element. A bright spot will be obtained at the top of the crt and this will be the reference spot which occurs at the beginning of the start element of each character. In the event of zero distortion this will be the only position that a spot occurs.

Distortion appears on the trace in the form of a second bright spot displaced to the left or right of the zero distortion spot. It should be noted that if the "distortion" control is turned counter-clockwise to the "short" sector, the distortion spot will move clockwise round the trace. With the "distortion" control in the central position the two spots should coincide. The spots will also coincide when either 50 per cent long or short start element distortion is introduced.

When monitoring incoming signals a group of bright spots will be apparent on the trace and the speed control should be adjusted for a stationary pattern when the signalling speed may be read from the controls. The amount of distortion in the signal is indicated by the length of the arc around which the spots extend and can be directly measured as a percentage from the scale. In the absence of any distortion all the spots will be superimposed so that only one spot will be visible on the trace.

Although the circuit of the TDMS5 is not unduly complex the setting up procedure is, and this should not be attempted without the full handbook and the facility of suitable test equipment. Any repairs should be limited to valve replacement and obvious component failure.

TDMS6

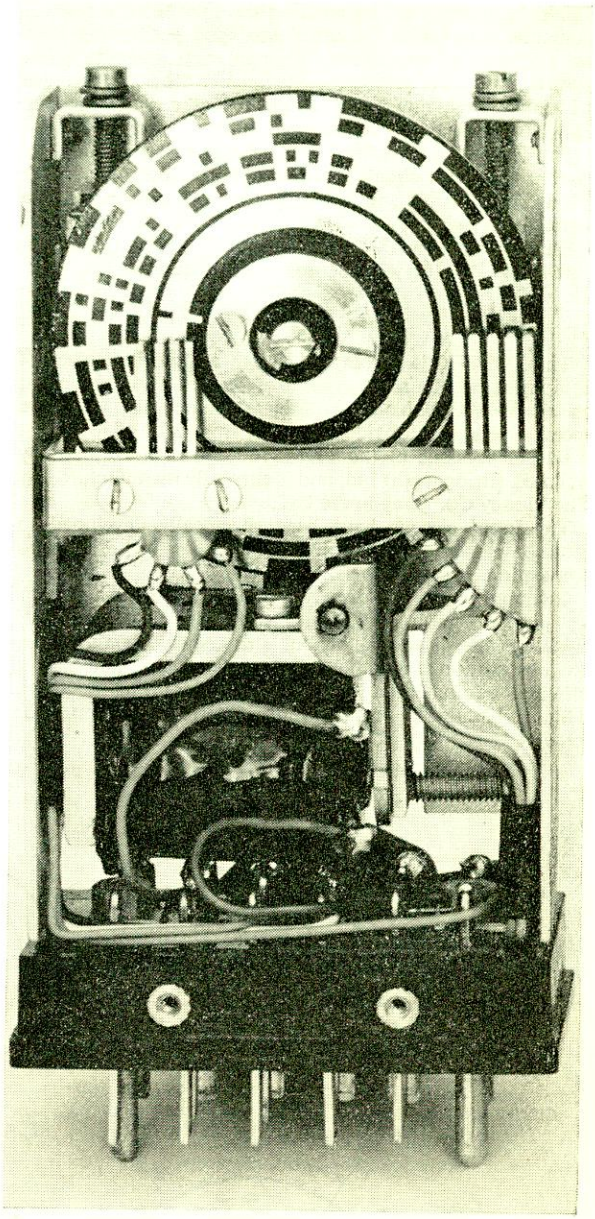
The TDMS6 is a companion unit to the TDMS5, the units forming a comprehensive test set up for the analysis of telegraph signals and equipment. The TDMS6 is essentially a receiving unit with the added facility of being capable of testing polar relays in the same way as the TDMS5.

Two different types of display are used for speed and distortion measurement. Speed measurements are obtained on a continuous circular time base as in the TDMS5. For distortion measurement, a triggered, or start-stop, spiral timebase is used for one element of a character, assuming the speed control has been correctly set. In all cases the required information is presented as a series of bright spots, or arcs, on the trace as illustrated in **Fig 9.14** (TDMS70).

The TDMS6 has the facility of being able to check single-current telegraph signals. Two types have been manufactured, the TDMS6 BV and the TDMS6 ABV.

The TDMS6 BV is fitted with line balance controls on each of the two inputs and for the correct operation of the instrument it is imperative that they are correctly adjusted. If the input signal is a perfect rectangular waveform with fast leading and lagging edges, it is only necessary to adjust the line balance control until the instrument functions.

In order to determine the correct settings of the line balance control on waveforms with slow leading or lagging edges, the upper and lower limits of instrument operation



The Telegraph Message Coder type TDA-10-1. This unit produces a 100-word test message and is fitted to many telegraph distortion measuring sets.

should be determined by rotating the line balance control from one extreme to the other and then positioning it at the midpoint of operation. Although measurements taken using this means of setting the line balance are a compromise it is unlikely that any difference will be noted in the amateur station as high line capacitance is uncommon.

The TDMS6 ABV is fitted with a single-current to double-current converter circuit and line balance controls are not fitted. The operation of the converter is controlled by the signal input switch.

The comments in this section on the TDMS5 are applicable to the TDMS6 with regards to maintenance.

TDMS70

The TDMS70 is a compact, fully-transistorized piece of equipment for the measurement of distortion at any point on single- or double-current telegraph circuits. Extensive speed coverage is provided, ranging from 30 to 330 bauds.

Earlier versions of the TDMS70 were manufactured by A.T.&E. (Bridgnorth) Ltd, and is currently manufactured by The Plessey Company in the UK.

The input circuits have been specifically developed to monitor low-level, 6–0–6 or 0–6V signals, in addition to conventional voltage levels.

Incoming signals are displayed on the crt against a circular or spiral timebase, providing a comprehensive analysis of signalling speeds and distortion. This display permits accurate observation and adjustment of telegraph type relays, terminal equipment and telegraph transmitting contacts, without having to remove radio interference suppressor circuits.

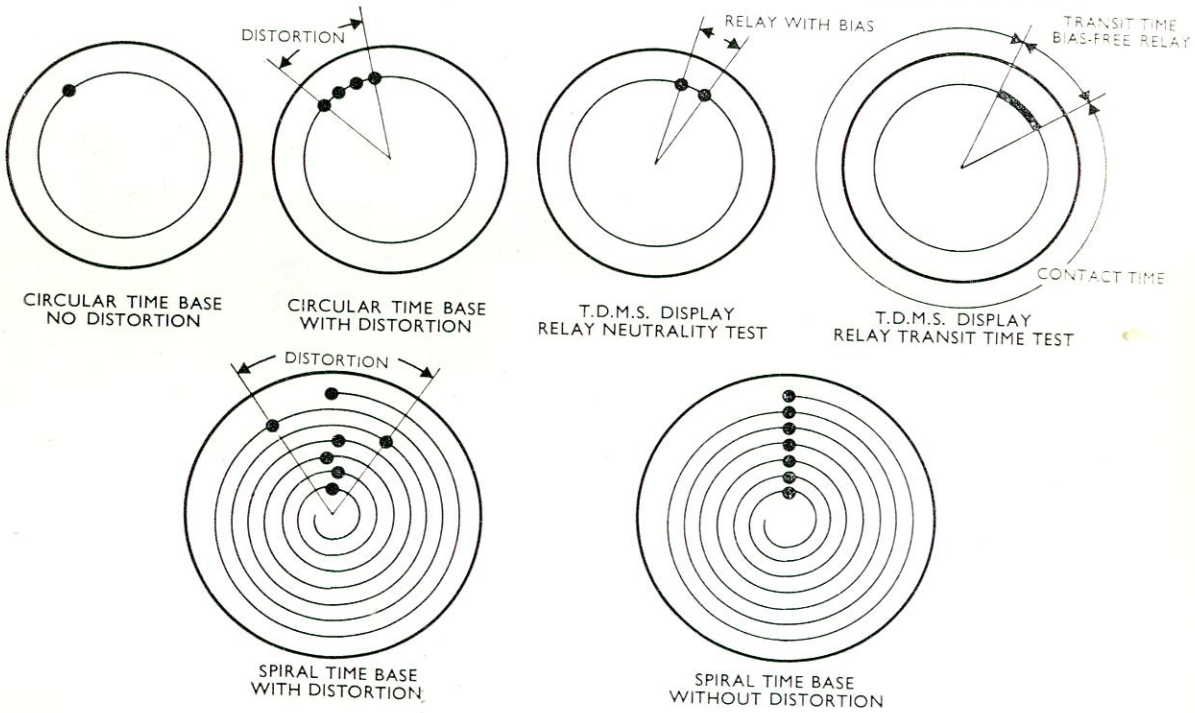
Fig 9.14 shows examples of the display and its applications using the circular and spiral timebase. The 3in diameter, flat-faced crt provides a continuous circular timebase display for monitoring synchronous signals, and a triggered spiral timebase display for measuring distortion on start-stop telegraph systems.

The continuous circular trace may be used to measure telegraph signalling speed and distortion where the signal is of a synchronous, or machine-generated isochronous, type, and providing the stop element has an integral number of half elements.

The unique spiral timebase permits observation of speed and distortion measurements of any type of telegraph signal, synchronous or isochronous. The timebase is triggered by the start element of each character, the number of spiral turns

The TDMS70 described on this page (Illustration by courtesy of The Plessey Co. Ltd).

Fig 9.14. TDMS70, examples of the display.



depending on the setting of the unit code switch, and is one-third of a turn less than that shown on the unit code switch.

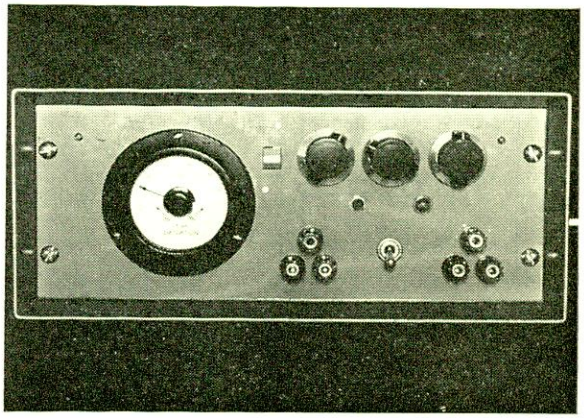
A dual concentric switch selects any unit code from 7 to 14 in one unit increments, and the continuous or spiral timebase. Selected transitions can be displayed by using a three-position switch, ie mark to space; space to mark or all. Three controls give a continuous speed coverage of 28 to 331 bauds. Coarse speed adjustment is made by a dual concentric switch and the fine speed control selects any speed between the coarse settings.

The equipment's high input impedance permits shunt monitoring without interference to a working system. A variable resistor, mounted on the rear panel of the instrument and calibrated in terms of the line current, is placed in series with the line when series monitoring. A neon lamp is located on the front panel that will flash each time there is a transition of the input signal. This may be used for checking transmission speeds with the aid of a strobe tuning fork.

The TDMS70 may also be used for setting up the length of the stop element of certain machines such as the Creed type 75, where this is variable. Provided the telegraph transmitter is a 5-unit code machine, set the unit code switch to 14, and let the machine run at cadence speed. If the requirement is a 7 unit character, all the signal transitions will appear at the top half of the spiral scan. When viewing a 7·5 unit transmission, alternate characters will appear at the bottom of the spiral trace. The reason for this being that the stop element is 1·5 units long and hence the commencement of the second character will be 7·5 turns of the spiral from the start. In the case of a 7·42 unit transmissions, the second character will appear at a point 42 per cent after the start of the first character. This corresponds to a 42 per cent distortion in a long direction (clockwise), as shown in the crt graticule.

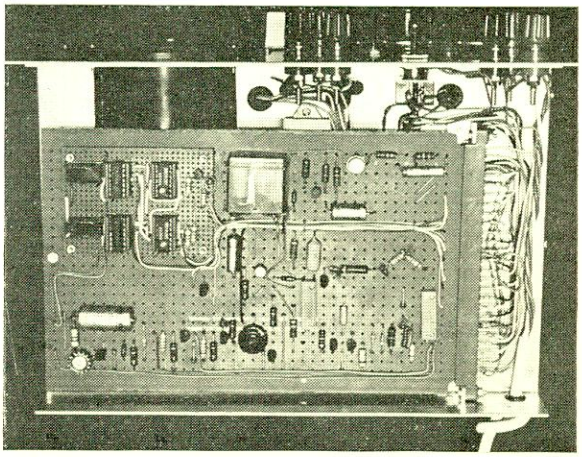
Power supply requirements are 40–60Hz, 105–125 or 210–250V.

Maximum signal input voltage is 200, and when series monitoring the current range is 15–60mA. The input terminals are isolated from earth, the mains earth being connected to the telegraph earth when required.



Above: **external view of a peak telegraph distortion measuring set.**

Below: **the wiring of the same instrument.**



Peak Telegraph Distortion Measuring Set

This instrument has been developed for the measurement of percentage deviation from the ideal character element length in a telegraph transmitter or signalling line. Input signals may be polar, single current or contacts. When checking polar signals the instrument is connected between the line and telegraph common, and the input voltage swing should be between 3–0–3 and 100–0–100V, the input resistance being approximately 100kΩ.

Single-current signals are measured by placing the unit in series with the line and restoring the loop current to the working value. The series resistor placed in circuit with the line is 500Ω, the voltage developed by the loop current across this resistor being converted to double-current signals in such a way that the half loop current voltage developed is the zero reference. Contacts, ie polar relays and double-current telegraph transmitting contacts, may be checked with the aid of the built-in set-reset flip-flop, provided there are *no* voltages present on the contacts, the contact supply being provided by the unit.

Single-current contacts may only be checked in their normal operating mode, ie in series with a loop supply and loaded with the correct current. A five-position input selector switch is provided to select the mode of operation and the mark polarity. In the case of single-current series monitoring the unit may be connected either way round in the loop, provided the indicated polarity is that which appears on the input terminal with respect to the telegraph common terminal when the loop current is flowing.

A terminal is provided for connecting the instrument case to the telegraph common terminal or for bypassing a floating input when used in areas of high electrical noise. This may be necessary in some instances owing to the high input impedance of the amplifier and the finite time that the input is open circuit during contact changeover.

Percentage distortion is only shown for a single element that is short in duration; however, mark, space or mark and space elements may be selected by a three-position switch. Errors in signalling speed are *not* indicated with the exception of short mark and space elements when the signalling speed is higher than that at which the instrument is set. For example, a 100 baud signal that has zero distortion will show

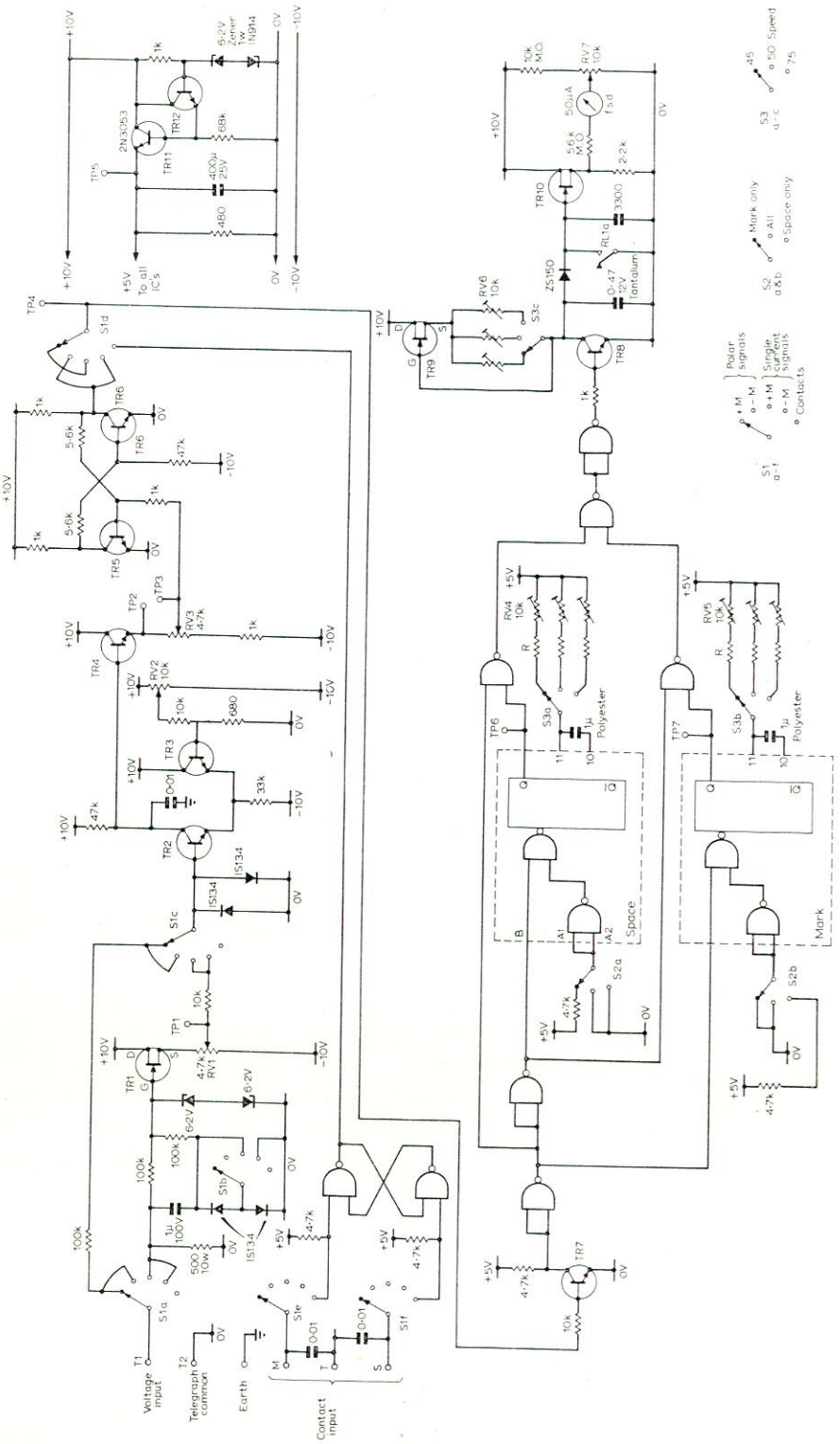


Fig 9.15. Circuit diagram, peak telegraph distortion measuring set. "TP" indicates test point; "MO" indicates metal oxide. All transistors 2N3705 except where indicated. All FETs are 2N3819. Zener diodes 6.2V, 400mW. For value of resistors marked "R" see text. All resistors ¼W unless otherwise stated.

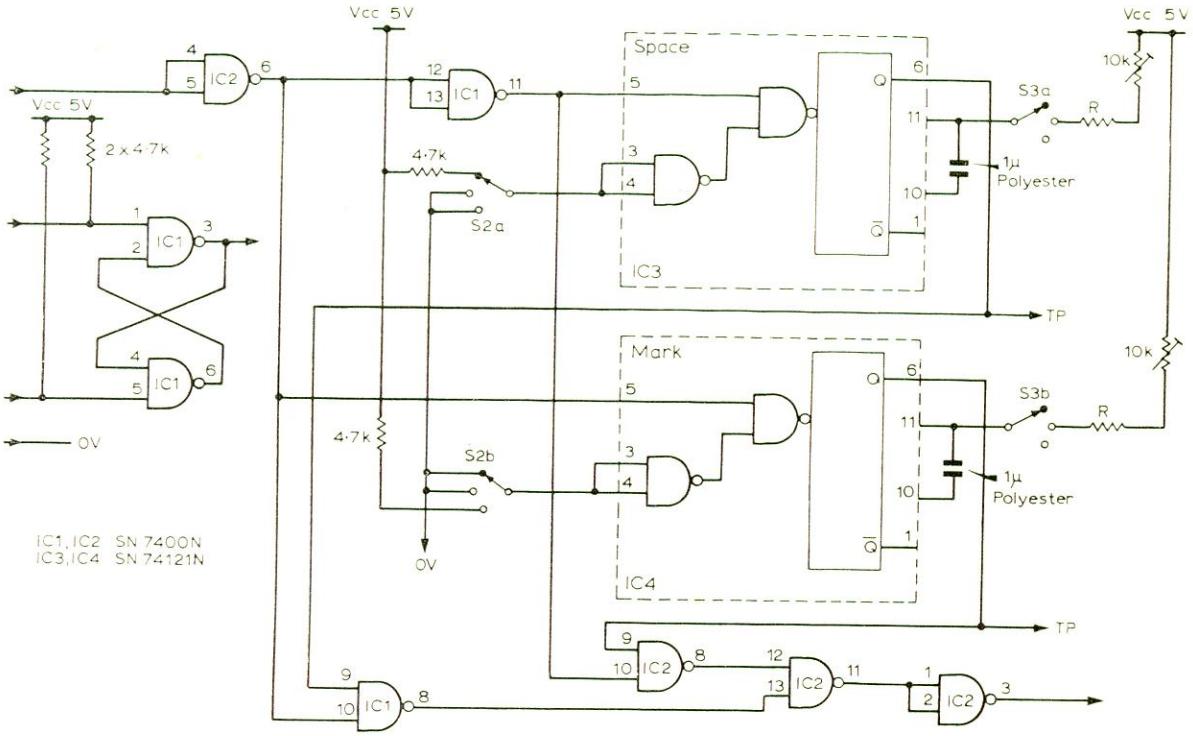
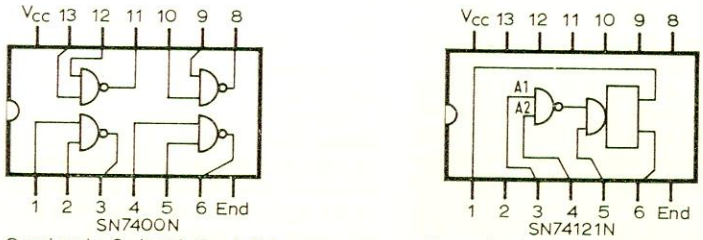
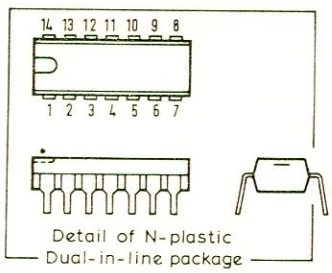
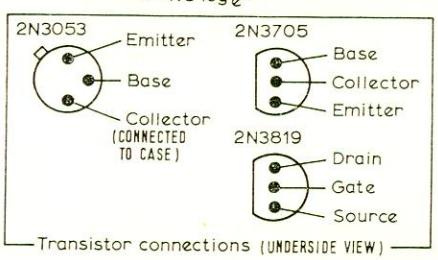


Fig 9.16. Enlarged schematic of integrated circuit connections and outline details of devices used in the peak telegraph distortion measuring set.


Vcc 13 12 11 10 9 8
1 2 3 4 5 6 End
SN7400N
Quadruple 2-input Nand Gate
A1
A2
SN74121N
Monostable Multivibrator
TIMING CAPACITOR BETWEEN PINS 10 AND 11
TIMING RESISTOR BETWEEN PINS 11 AND Vcc
T = RC log e 2





as 50 per cent distortion when checked with the instrument calibrated for 50 bauds.

The response time of the instrument is fast enough for the meter to read within 1 per cent of the distortion for a single distorted element at the input. The meter is reset periodically either by a two-speed oscillator built into the unit, or manually. The fast reset is useful for setting up polar relays energized by 1.1 reversals, but is of little use with normal telegraph signals. The slow reset operates every 10–15s and is useful for normal telegraph signals. A manual reset is provided when monitoring is required over periods up to 10min.

Circuit Description (see Fig 9.15)

Double-current signals are applied to the base of TR2 via 100kΩ resistor and clamping diodes. TR3 is emitter coupled to TR2 to enable a true zero crossover reference to be maintained in the amplifier TR2 and emitter follower TR4. The flip-flop TR5 and TR6 is used to clean up the signals and has conjugate outputs for sense switching to define the mark and space signals irrespective of the input polarity. When the input current is correctly set up the flip-flop will only change state if the input voltage crosses zero to a value greater than about 1V, hence no change occurs when the input is open circuit, ie during contact travel, thus eliminating contact bounce.

Single-current signals are converted to double-current in the gate circuit of TR1 in conjunction with the 500Ω 10W loop series resistor.

The output of the flip-flop is converted to voltage levels suitable for the integrated circuits by TR7. The output of the flip-flop connected to the base of TR7 is +10V when the input is the mark condition. Switch S1 will ensure that this condition applies independent of the polarity of the mark input.

Two monostable multivibrators IC3 and IC4 are used to generate pulses of the correct duration for each mark and space element in the input signal. IC3 will produce one output pulse for every signal transition from mark to space and IC4 a pulse for each space to mark transition. With the use of NAND gates, the output of pin 3 of IC2 will be a negative pulse having a width equal to the amount the input pulse is shorter than the pulse generated in either IC3 and IC4. Should the input pulse be longer or two adjacent pulses be the same state, there will be no output pulse. Any pulse present turns TR8 off to enable the constant current generator TR9 to charge the 0·47μF and 3,300pF capacitors at a rate determined by the setting of RV6 and position of S3c. The voltage developed across the capacitors will be proportional to the duration of the pulse, and at the end of the pulse the charge on the 0·47μF will be removed by TR8 conducting. The charge remains on the 3,300pF, being isolated by the ZS150 (very low leakage) diode. A source follower TR10 is used to monitor this voltage, RV7 being provided to set the meter to zero thus overcoming the Idss of TR10. Charge on the 3,300pF capacitor is removed by the momentary closure of the relay contacts RLa.

Two cross-coupled, two input NAND gates (part of IC1) form a set reset flip-flop for use when checking polar contacts.

Construction

The simplest method of construction is by the use of perforated board and terminal pins. It is recommended that sockets be used for the integrated circuits. Those variable resistors marked with an asterisk should be multi-turn trimmers and preferably of cermet construction for infinite resolution.

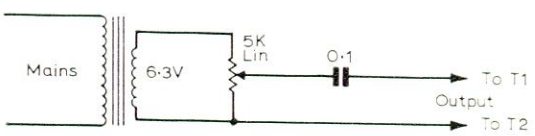


Fig 9.17. Test circuit.

Setting Up and Calibration

After carefully checking the wiring and with the integrated circuits removed, apply power and measure the +ve and −ve10V supply rails and the output of the 5V regulator at TP5; this must be within 0·25 of 5V. With no connection to the input set RV1 for 0V at TP1. Hook up the test circuit as shown in **Fig 9.17** and connect to input terminals T1 and T2. With a voltmeter connected between TP2 and T2, the output of the test circuit set to zero, turn RV2 from one end of its range to the other, noting the maximum and minimum voltage at TP2. Calculate the mean voltage and apply maximum ac to the input from the test circuit then adjust RV2 until the voltmeter reads the calculated value.

Slowly reduce the output of the test circuit, keeping the voltage at TP2 the same by adjustment of RV2 until the voltage suddenly jumps to either minimum or maximum. Increase the input by a small amount and transfer the voltmeter to TP3, setting RV3 for 0V. This procedure will set the input circuit for maximum sensitivity.

Replace the integrated circuits and set RV4 and RV5 to their mid positions. Temporarily connect a 50kΩ variable resistor in series with RV4 and the Y amplifier input of an oscilloscope to TP6. Using a calibrated low frequency oscillator connected to the X deflection circuit of the oscilloscope and also to the input of the instrument via an 0·1μF capacitor, set the output level of the oscillator to about 6V peak to peak at a frequency in hertz equal to the baud speed being set up. Switch S2 to the mid position "all" and with the temporary 50kΩ variable set to maximum turn on the power and set up the oscilloscope to see the resulting waveform.

Decrease the resistance slowly until the trace becomes two distinct lines of equal intensity. The final waveform should be high and low for alternate sweeps of the X input. This procedure sets the reference pulse length equal to the period of the input signal, ie bit duration or speed in bauds. Switch off power and remove the 50kΩ variable resistor, replacing it with a fixed resistor of the nearest preferred value such that by adjustment of RV4 the original resistance in circuit is restored. Turn on the power and with RV4 set to maximum, slowly decrease its resistance until the previous conditions are restored. Install a fixed resistor of the same value in series with RV5 and with the oscilloscope connected to TP7 repeat the above procedure. Disconnect the oscilloscope and oscillator and switch S4 to "fast reset". Check that the relay is operating and set RV7 to zero meter reading. Reconnect the oscillator to the input and the frequency set as before, set RV6 to minimum resistance, S2 to "mark only" and S4 to "manual reset"; slowly increase RV6 until the meter is at fsd. Operate the manual reset button and the meter should flick downwards momentarily.

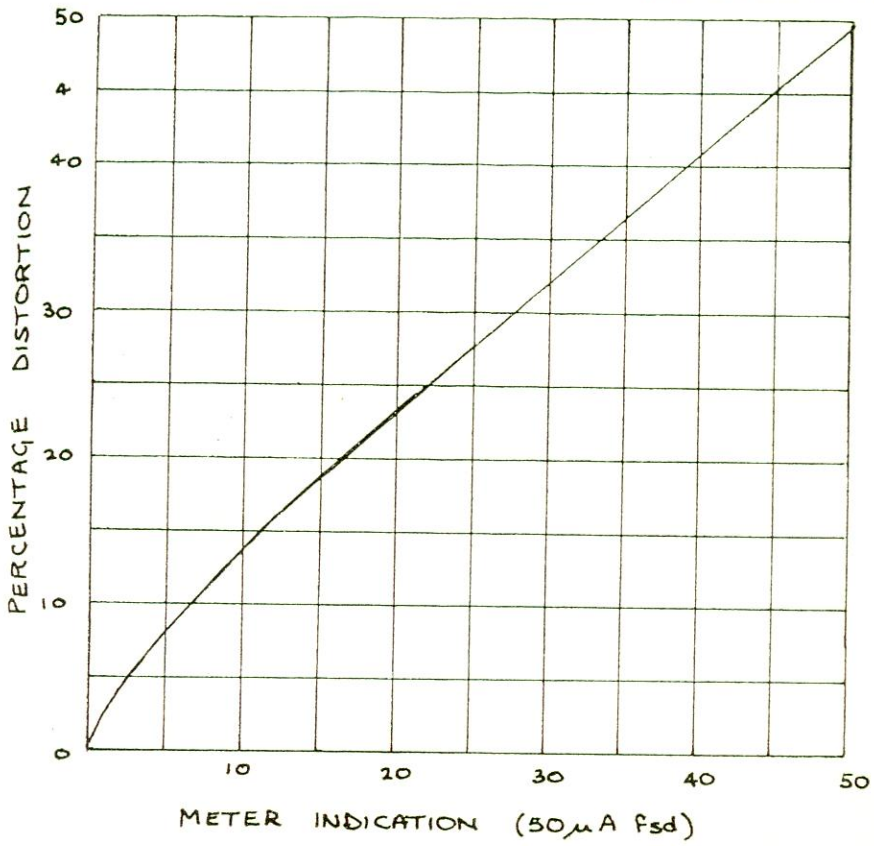


Fig 9.18. Calibration curve for peak distortion meter.

Switch S2 to "space only" and reset. The meter should read the same if all has been set up correctly. If this is not so, recheck the setting of RV2 and RV3, then repeat the final adjustments of RV4 and RV5.

The meter may be calibrated by changing the oscillator frequency according to the following formulae:

$$f = \frac{1}{2\,(1/B - D/100B)}$$

where f = frequency in hertz
B = speed in bauds
D = distortion as a percentage.

The calibration curve shown in **Fig 9.18** was that derived from the prototype instrument; the meter scale being redrawn to indicate percentage peak distortion.

NOTE: The calibration accuracy depends on the oscillator calibration.

Repeat the above procedure for any other speed that may be fitted.

To measure the peak distortion of double-current telegraph signals, connect the input terminal T1 to the signalling line and T2 to the telegraph common earth. Set the "speed" switch S3 to the signalling speed, the input selector S1 to polar signals of the correct mark polarity, the "reset" switch S4 to "manual" and press the reset button. With the "element" switch S2 in the "all" position, the meter will indicate the percentage distortion on any mark or space elements received, with S2 in the "mark" position the indication will concern the mark elements only in terms of short duration and similarly with S2 in the "space" position the meter will indicate short duration space elements.

When measuring single-current signals, connect the input in series with the loop, terminal T2 towards the earth end of the loop, and reset the current. Set the input selector switch to the appropriate position and measure the distortion as previously described.

Provided the signalling speed is correct, an indication of short space elements will mean that the mark element is also too long and likewise short mark elements mean that the space elements are too long. By careful selection of the characters used for testing, faults in transmitter contact assemblies can be located. It must be remembered, however, that faults such as split elements (see chapter 3) can produce figures for distortion well over 50 per cent, hence the instrument must be used with some degree of caution and an understanding of its operation.

To set up a polar relay using the instrument described, connect the contacts to the terminals marked mark (M) tongue (T) and space (S). Arrange a low frequency oscillator to drive the relay coil at a frequency (in hertz) about 10 per cent higher than half the baud speed setting of S3. Switch

the reset S4 to "fast" and adjust the bias of the polar relay for minimum meter indication with S2 set to "all". Reduce the oscillator frequency to exactly half the baud speed setting and measure the distortion.

TSGS (TELEGRAPH SIGNAL GENERATORS)

Mechanical types of telegraph signal generators are extremely useful for checking teleprinters. They often take the form of the Teletype 14TD with a somewhat modified distributor plate as shown diagramatically in **Fig 9.19**. Provided the motor speed is correct useful measurements of the range of a receiver may be obtained, although it is limited to the lengthening or shortening of the start element. With care it is possible to modify the distributor plate of a 14TD to produce a signal generator capable of transmitting signals of known distortion, although any modifications must not be undertaken lightly as it would be very easy to wreck an otherwise perfectly good TD.

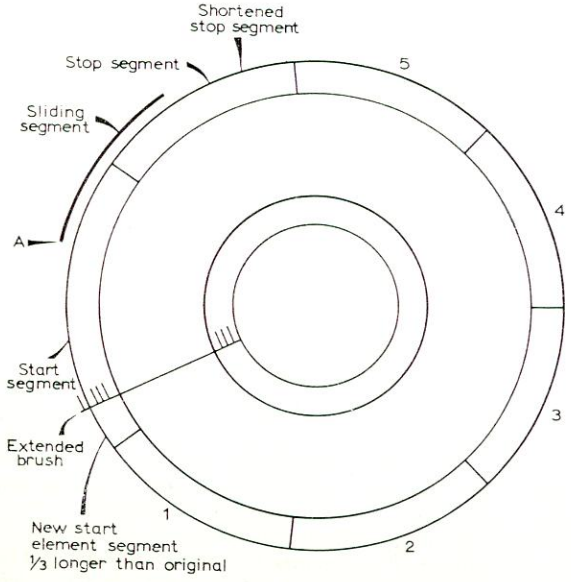


Fig 9.19. Suggested modification to a 14TD for converting to a telegraph signal generator. The position of the sliding segment will control the duration of the start element and must be electrically connected to the stop segment. The outer brush must be extended to wipe the sliding segment. Calibration may be by direct angular measurement.

TSG 10

The TSG 10 is a comprehensive, low cost, fully transistorized and compact telegraph signal generator. This equipment is currently manufactured by The Plessey Company in the UK, earlier versions having been manufactured by A.T.&.E (Bridgnorth) Ltd.

A stable frequency source and digital techniques eliminate calibration and permit simple, precise control. The TSG 10 generates a 5-unit signal plus a 1-unit length start element and a switch selected stop element length of 1, 1·5 or 2 units.

Three fixed speeds may be selected within the range 45–75 bauds, although the standard model has a three-position switch, preset to select 45·5, 50 or 75 bauds.

Mark or space bias, or long or short start element distortion, can be applied to the output signal in fixed increments of 5 per cent over a 0–50 per cent range. A five-position switch provides the following output signals:

(*a*) continuous mark;
(*b*) continuous space;
(*c*) any repeating character set up by the five keys;
(*d*) a 100-character test message generated by an electromechanical coder;
(*e*) 1 : 1 reversals. (By using the keys and an 8-unit code, 2 : 2 reversals may be generated.)

The output relay requires external signalling supplies, and hence may be externally wired for single- or double-current signalling, at high or low levels. The Carpenter electromechanical relay type 3N1Z is fitted to all standard models. Alternatively, the Plessey TER 10 electronic relay may be fitted as plug-in replacement.

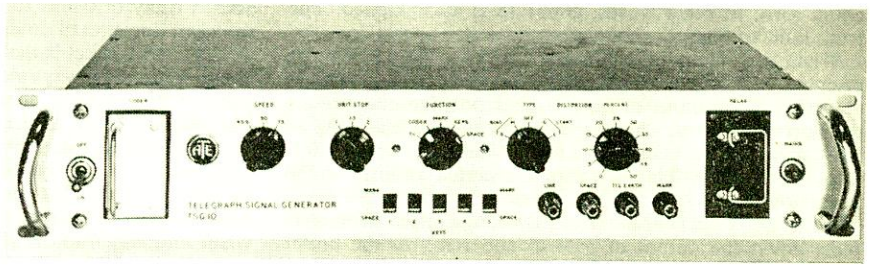
The Plessey coder type TDA/23 is incorporated in the TSG 10 to generate the 100-character test message.

Oscillator stability of the TSG 10 has a long-term drift not greater than +0·2 per cent, and a temperature coefficient of 50 parts in 10^6/°C. Mains power supply requirements are 105–125, or 210–250V, 40–60Hz ac.

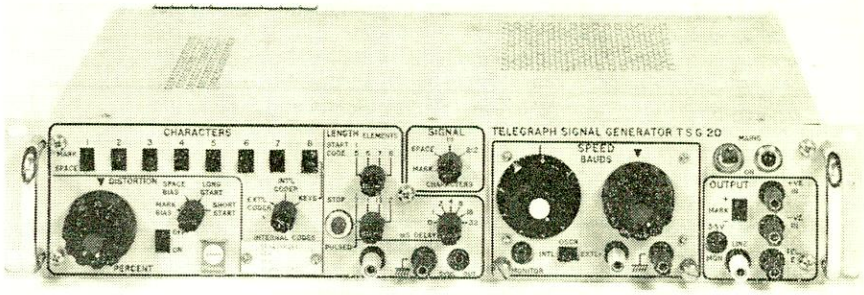
TSG 20

The TGS 20 is one of the latest telegraph signal generators to be manufactured in the UK by the Plessey Company. It is a solid state signal generator and is designed for both line and machine testing, utilizing a comprehensive range of 5, 6, 7 and 8 unit code signals. The fully protected electronic relay output is capable of switching double-current signals from 3–0–3 to 115V of 6–230V single current, both at up to 100mA. Test signals are provided from 20–5,000 bauds, utilizing either a plug-in unit or an external oscillator. There are two plug-in units, variable or preset, giving a continuous range from 30–330 bauds or fixed speeds from 42–4,800 bauds respectively. Signals over the full range can be generated by using the external oscillator. These test signals can have start element or bias distortion added in 1 per cent steps up to 49 per cent. An electronically generated test message of eight characters, suitable for line testing, is an inbuilt feature of the TSG 20. For machine testing, where a longer test message is required, the coder box TCB 10 provides test messages of up to 100 characters in length. Maximum character rate with the external coder being 30/s, with 5, 6, 7 or 8 level codes. Any repeating character of the

Two versions of the TSG10, on the right the earlier version made by A .T. & E., and on the left (p 9.18) the current version by the Plessey Company, who supplied this picture.



The TSG20 Telegraph Signal Generator described below. (Illustration by courtesy of the Plessey Co. Ltd).



appropriate code selected by the front panel switches may also be transmitted, together with continuous mark or space, 1 : 1 or 2 : 2 reversals.

The TGS 20 has been designed to provide test signals in either a continuously repeated sequence or character by character. An external pulse derived from the equipment under test controls the character release facility. A front panel control allows selection of the delay, in the character release mode of 1, 2, 4, 8, 16 or 32 ms after receipt of the release pulse. A push-button adjacent to this control allows manual release of individual characters.

Output relay protection is such that the equipment is protected against incorrect connection of the telegraph supply, and also accidental short circuits. Standard rf suppression is provided but a simple change enables the suppression circuits to be disconnected if necessary. A front panel switch enables the output polarity to be set for positive mark or space as required. Links are provided to enable the user to set the eighth bit in the CCITT No 5 alphabet for parity checking, even or odd parity, mark or space.

RTTY SIGNAL GENERATOR

Teleprinter range adjustments and other performance checks are often made while the machine is printing the standard RY test signal. R signals select even mark and odd space pulses, then Y signals reverse everything and select even space and odd mark. The result is a maximum amount of slipping and sliding of adjacent parts within the machine, and conditions which are likely to cause misprint are readily observed.

This unit is a low cost reversal generator which sends repeating zero bias RYRYRY test signals to the printer or transmitter loop. An electronic clutch is included, making the unit a self-contained, solid-state transmitter distributor. A clutch keyer may be added later if desired. This enables the generator to send " . . . . RY (pause) RY (pause) RY . . . . ," leaving both hands free for stubborn machine adjustments.

The circuit of **Fig 9.20** generates the RY waveform as a 7 unit code, ie the stop pulse duration is equal to the duration of the code elements. Gates E and F of the MC824P quad-two-input gate are connected as an astable multivibrator. The negative slopes of the multivibrator output trigger flip-flop A (MC890P) to form a perfect square wave. Gate H is used as a buffer to drive the base of the Motorola MJ421 transistor with the square wave. The MJ421 is rated at 350V vcb and makes an excellent single-current loop driver. Diode D4 is for inductive transient suppression. Resistor Rb is added to decouple transients from the ic logic. The remainder of the circuit is used to invert two out of every 14 square wave pulses to form the RY test signal.

Flip-flops A, B, C and D form a scale of 16 counter. Feedback capacitor C4 inverts one pulse by causing count 2 to be skipped. This occurs during the decay of the positive pulse fed through the capacitor from flip-flop D, which retriggers A and causes an immediate advance to count 3. Gate G inverts the other pulse by presetting count 15 to

count zero. In other words, count 15 is also skipped. The truth table of **Fig 9.22** summarizes generator operation.

When S1 is closed, the circuit advances to the mark pulse of count 14. Gate B recognizes this count because all inputs are zero. The output of gate B goes positive and presets flip-flop A to mark. The circuit holds the mark as long as S1 remains closed, because the preset line will not allow flip-flop A to toggle. This provides the clutch action for the generator.

When S1 is opened, the positive voltage at R5 (from A1) pulls down the output of gate G and removes the preset condition from the first flip-flop. The next trigger from the multivibrator momentarily advances the circuit to count 15. Then the positive voltage disappears from R5, causing the output of gate B to rise. The positive output from G rapidly reactivates the preset line and forces the circuit on to count zero. Gate G has no further influence until count 15 is reached again (or count 14 if S1 gets closed). Capacitor C3 adds a delay of 0·5ms to ensure that the preset pulse is of sufficient duration to do its job.

The overall effect is that only complete RYs are sent. The circuit action is always stopped in the proper state to begin another RY. If S1 is opened and then closed, a single RY will be sent. If S1 is opened continuous RYs will be sent until it is closed, when it will stop at the end of the letter Y.

Construction may be with the aid of a printed circuit board or by using ic sockets and wiring with fine hook-up wire preferably with that having ptfe insulation to avoid trouble when soldering into the socket pins. Pin connections are not shown in **Fig 9.20** so the device orientation may be left to the constructor. Each integrated circuit requires a positive supply voltage and ground connections; 3–4V at about 75mA are required to power the unit; two flashlight cells should be satisfactory.

Teleprinter loops are capable of some very high transient voltages, in some cases as high as 800V. Avoid ground

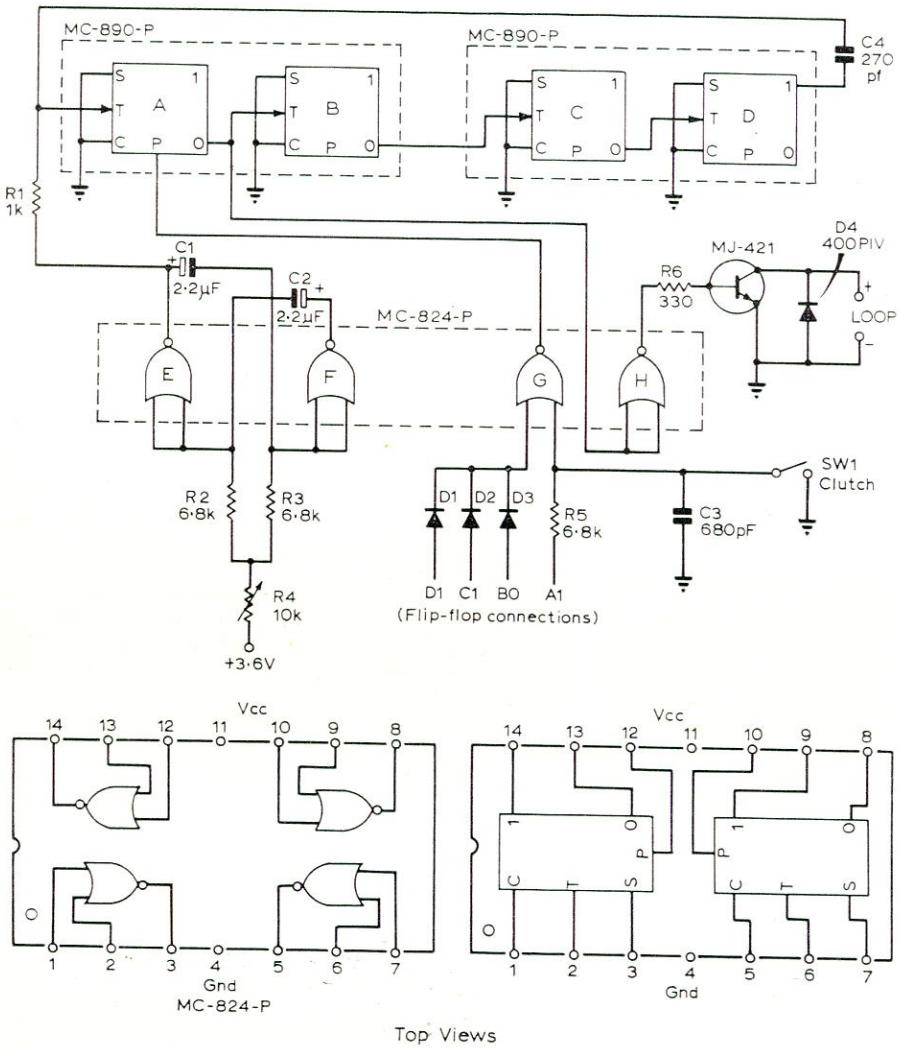


Fig 9.20. Solid state RY generator. Diodes D, D_2 and D_3 are germanium computer types. Silicon diodes may be used with higher supply voltage (3·5–4·5V).

loops and long leads common to the loop and generator supply. A particularly noisy loop may require a 0·1μF disc ceramic capacitor between the Vcc and GND pin of each ic. The polarity of the loop is important.

Only one adjustment is required. Open S1 and set the speed control R4 for such that the output of the multivibrator is equal to the baud rate in hertz. The most accurate means

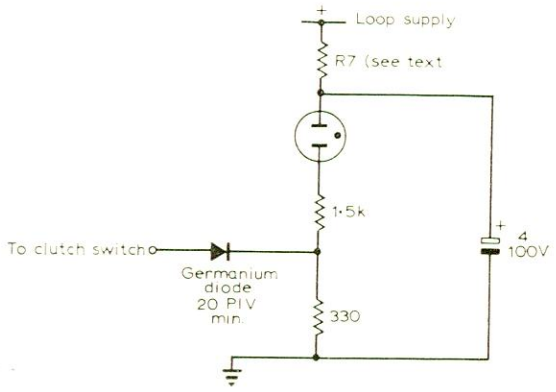


Fig 9.21. Clutch keyer circuit.

being with the aid of a frequency counter. Alternatively the frequency may be set with the aid of an oscilloscope and a standard frequency utilizing lissajous patterns.

A simple clutch keyer is shown in **Fig 9.21**. Note that the RY generator's clutch control is grounded through the diode and 330Ω resistor. The ground inhibits generator operation. Every few seconds the neon relaxation oscillator fires and momentarily reverse biases the diode, which effectively removes the ground from the clutch. As a result, one single RY is sent at a time—every 2s. R7 is about 2·2MΩ for each 100V of loop supply.

Count	Ao	Bo	Co	Do	Output
0	0	+	+	+	Mark (stop)
1	+	+	+	+	Space (start)
2	0	0	0	0	pos. transient—0·5s
3	+	0	0	0	Space
4	0	+	0	0	Mark
5	+	+	0	0	Space R
6	0	0	+	+	Mark
7	+	0	+	0	Space
8	0	+	+	0	Mark (stop)
9	+	+	+	0	Space (start)
10	0	0	0	+	Mark
11	+	0	0	+	Space
12	0	+	0	+	Mark Y
13	+	+	0	+	Space
14	0	0	+	+	Mark
15	+	0	+	+	neg. transient—0·3s
0	0	+	+	+	Mark (stop)

Fig 9.22. Truth table for rtty generator.

Setting Up the Station for Self Checking without Test Gear. Adjustments to Make and Faults to Look For

The teleprinter should first be connected for local operation. Check the voltage available for the loop when on load and also the loop current. These should be within 10 per cent of design or better. For machines fitted with polar selector magnets, move the receiving camshaft off of the rest position by rotating the motor by band and with the loop supply disconnected check that the force required to move the magnet armature from side to side is equal. Continue to rotate the motor by hand in its direction of running and ensure that the selection of the code elements are correct according to the position of the magnet armature. If these conditions are not satisfied adjustments will have to be made before the application of power (see chapters 2 and 3) While operating the machine by hand, check that there are no "tight" spots; everything should be quite free, except possibly at the printing or punching function point during the cycle of operation. In going through this exercise, endeavour to follow the various functions to gain some understanding of the operation of the machine.

Fault finding and adjustments are difficult to describe as the number of combinations possible are infinite, hence a full understanding of operation must be obtained before any attempts are made to correct the faults by adjustment. For machines in amateur hands it is often difficult to obtain spares to replace worn parts, and adjustments different to those quoted by the manufacturer often have to be undertaken to maintain operation. Before any adjustments of this nature are undertaken, assistance should be obtained if at all possible from someone who knows the type of machine, and it should be remembered that any settings made with the machine in the rest position may be different when under motor power owing to the inertia of the moving parts.

If the machine is of the receiving type and is fitted with an orientation device, all the initial checks should be done with the lever set at the mid-point on the scale. When the machine is connected in a local loop, the orientation lever should be slowly moved first in one direction and then in the other maintaining correct copy to determine the range of the system being checked, returning the lever to the mid-point of the adjustments and remembering the position where correct copy ceased. The system should then be arranged to work through the terminal unit, and for this test an afsk ocsillator is necessary if an af type of terminal unit is being used. Connect the output of the afsk oscillator to the input of the terminal unit via an attenuator to obtain a similar level of input signals as to those from the receiver. The transmitting contacts must be wired to the afsk oscillator completely separate from the receiver selector magnet circuit and the terminal unit output. Make sure the loop current is satisfactory and turn on the power once again. Recheck the range and operation of the machine. If the range is significantly different the following points must be checked individually and corrective action taken:

Tone frequencies and levels, discriminator or detector output of terminal unit, terminal unit output relay bias and any pulse shaping circuits within the terminal unit.

When all the above is satisfactory the system may be connected up to the receiver and signals printed off the air, provided the speeds are compatible.

If the machine used for reception is a receiver only or has a mechanical coupling for local copy, most of the above checks can only be made with a second machine with a transmitter or an auto transmitter. It is always possible that a machine will work first time but there are many faults that can arise and it is again stressed that a complete understanding of machine operation is essential to prevent unwarranted despair with rtty.

CHAPTER 10

CONTROL SYSTEMS

TO an amateur just beginning to set up a station on rtty, or to add rtty to an already existing station, interconnection and control of rtty gear will not seem a very important subject. However, as he progresses in the subject, and acquires more gear, the point will come when he sits back and looks at his station and decides that some rationalization in the control of the various machines is necessary. It is the purpose of this chapter to discuss how this may best be done, using various control systems.

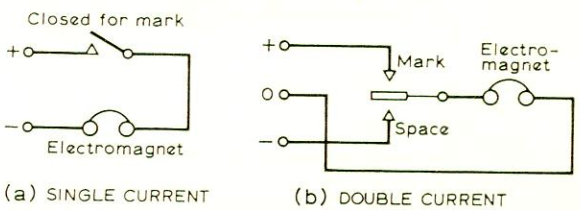
In a typical amateur rtty station there are two main parts of the control system. The first of these is concerned with the current flowing in the coils of the electromagnet in the teleprinter or reperforator, etc and the associated transmitting contacts (eg the teleprinter keyboard). This is known as the "loop", and will be dealt with in detail below. The second part of the system is concerned with such functions as changing over from transmit to receive, or, for example, if several alternative terminal units were available, switching the outputs of these to operate the teleprinter with the desired terminal unit.

There are two basic types of loop circuits, single current and double current. In a single-current loop current flows in the mark condition and a space is signified by zero current flowing. In a double-current loop a mark is signified by current flowing in one direction and a space by current of equal magnitude but of opposite polarity. The difference between these two types of loop is illustrated in **Figs 10.1a** and **b.** The values of voltages shown are typical ones used in these types of loop circuits. It can be seen from these two circuits that there is a difference between a single-current teleprinter and a double-current teleprinter. In a single-current printer the transmitting contacts (associated with the keyboard) will electrically consist of a simple on/off switch, and the electro-magnet must be mechanically biased to the space position (eg with a spring) so that when no current is flowing the armature of the magnet moves to the space position, and when current again flows the force produced on the armature of the magnet is strong enough to overcome this biasing, and the armature returns to the mark position. On the other hand the keyboard contacts on a double-current teleprinter are electrically equivalent to a two-way, single-pole switch. The condition of the electromagnet is also different from the single-current type in that it is not biased at all and is usually bi-stable, ie with no current flowing will stay in either the mark or space position. In a double-current loop, however, current is always flowing in one direction or the other and thus the armature of the electromagnet is forced over to the appropriate position and held there, for the duration of the pulse.

It should be noted at this stage that a teleprinter consists of two parts—a receive part and a transmit part, the former being the electromagnet and the latter the keyboard contacts. In fact it is possible to classify all rtty gear that may be connected in a loop as either transmitters or receivers. Thus things such as auto-transmitters, relay contacts, terminal unit outputs, tdms outputs are all transmitters, whereas reperforators, relay coils, tdms inputs are all receivers. Since a teleprinter consists of a transmit and a receive part, which are only mechanically connected in that they are driven by a common motor and are mounted on the same chassis, it is necessary to provide an external circuit or loop before the machine will even produce local copy (ie act "like a typewriter").

It should be noted that both single- and double-current methods are in current use today and it is necessary to decide which system is to be adopted for the station control system. Teleprinters are available for use in single- or double-current loops. Machines manufactured by Creed and Co Ltd are double-current types and have a two-way switch for the transmitter and a zero biased, bi-stable magnet as described earlier. Machines manufactured by most other companies, eg Teletype, Siemens, etc are invariably single-current types. It should be noted that although it is impossible to use a single current machine directly on a double-current loop, it is possible to use a double-current machine in a single-current loop. This is done by simply ignoring the "space" contact on the changeover switch of the keyboard contacts and providing biasing on the armature of the magnet. (In the case of the Creed machines, this is done by a special bracket and spring which is screwed on to the base plate near to the magnet, but on many machines bought on the amateur market this bracket is absent.) For best results when using a Creed machine (eg a 7B) on single current the connections to the coil should be changed.

At first sight it may seem that single-current working is by far the easier and simpler to use. However, considerations on the distortion in the loop due to the inductance of the coils make it necessary to use a higher voltage and current in a single-current loop. These higher values tend to lead to increased sparking at the keyboard contacts, and this as a



Figs 10.1a and b. Single and double current loops.

result leads to hash in the receiver. Typical values for a single-current loop are approximately 110V and a current of 60mA; in a double-current loop the voltage is reduced to approximately 80V and the current to 20mA for a Creed 7B machine. Also, the fact that a double-current system is more "balanced" than a single-current system leads many amateurs, and commercial operators, to use a double-current system. Amateurs, however, may not select which sort of machine they want, and if they have a 7B they may only be able to find a Teletype TD14 auto (single current) at a price that they can afford. However, it will be seen later that by the use of high-speed relays it is possible to key a double-current loop with a single-current auto-transmitter, or use a single-current receiver (eg reperforator) in a double-current loop.

Having decided on a double- or single-current system we may now turn our attention to the circuit of the loop. For the rest of this chapter the circuits will be based on the popular Creed 7B teleprinter. But wherever single current is used another machine may be used.

Initially the arrangement for connecting up a 7B to obtain "local copy", ie act like a typewriter in that whatever is typed on the keyboard will appear on the paper of the same teleprinter, will be studied. The arrangement for doing this is shown in **Fig 10.2** for single or double current respectively. It will be noticed that in the single-current circuit, the space contact on the transmitter is not used and that the armature of the magnet is mechanically biased to the space condition. One feature that is common to both circuits is the variable resistor and the meter. The meter need not, of course, be wired permanently in circuit, but it will be found of great use if it is. In the case of the double-current circuit a centre zero meter should be used. At first sight it may seem curious that a high voltage is used in conjunction with a limiting resistor which is adjusted to give the required current. Since the resistance of coils is approximately 400Ω, it would be possible to obtain the required line current with a voltage of only 8V. The need for the high voltage is because of the inductance of the coils which tend to hinder the change in the current, but this effect is minimized by using a high voltage.

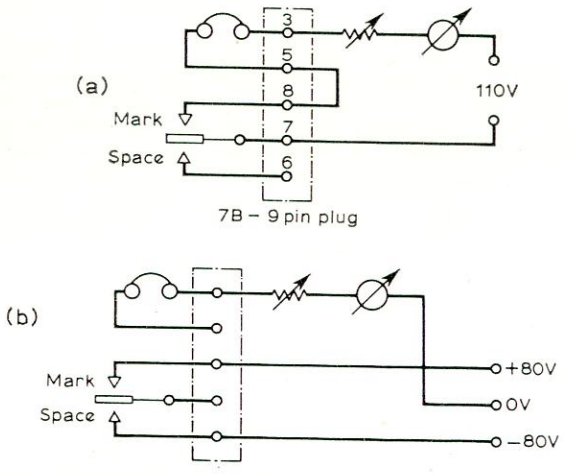
Thus by using either of the circuits in **Fig 10.2** it is possible to use the teleprinter as a typewriter and produce local copy. It is worth noting that correct printing will be obtained whatever the speed of the motor since the receiving and transmitting mechanisms will always be in synchronization, as they are driven by the same motor. It is possible to obtain local copy in this way by rotating the teleprinter motor by hand; in this way, by observing the moving parts of the machine, it is easy to see how it operates.

Now that the teleprinter is operating from its own keyboard, and any adjustments that may be necessary to obtain correct printing have been carried out, the next step is to use it to receive signals, and we will assume that these signals come from a terminal unit fed from a receiver tuned to a station of known speed, shift, etc.

Like teleprinters, most terminal units are designed to work into either double- or single-current loops, and the same limitations arise in their connection into different types of loops. A common type of output stage in a terminal unit, especially in double-current types, is a polar relay which may be used to key either a double-current or a single-current loop. The method of connection is similar in principle as described for the local copy arrangement above. The keyboard contacts of the teleprinter are merely replaced with the contacts in the terminal unit. It should be noted that at this point it will be necessary to adjust the speed of the teleprinter motor accurately to be the same as the received signal, so that the receiving mechanism stays in synchronism with the incoming signal. Having set up the receiving side of the station it is now necessary to consider the method of keying the transmitter.

It is not the purpose of this chapter to discuss the various methods available for producing fsk from conventional transmitters, we will merely assume that all these methods of keying will require a simple switching function (eg one connection to be earthed, or two terminals to be shorted). In any event it is a simple matter to connect the teleprinter keyboard contacts in such a way as to obtain the necessary keying function. A diagram of this simple transmit/receive system is shown in **Fig 10.3**. This is the simplest rtty system available and has one immediately apparent drawback when used on the air. However, before going on to this, let us consider the difficulties of keying a double-current loop with a terminal unit that has a single-current output.

The output stage in a single-current terminal unit is very often a valve, the magnets being placed in the anode or cathode circuit. Thus the output from the previous stage is applied to the grid of the valve and the current through the valve is arranged to vary between 0–60mA, say. Thus it is not possible to directly key a double-current loop with a tu having this sort of output. An example of this type of tu is the circuit designed by DL6EQ, which is in fairly common



Figs 10.2a and b. Single and double current loop connections for the Creed 7B.

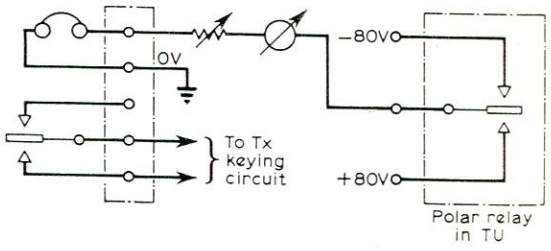


Fig 10.3. A simple transmit/receive system.

use in this country and through the rest of Europe. To convert the output from single current to double current, a high-speed polar relay is used. The method is to connect the relay coil in place of the printer magnets so that the relay is keyed by the output from the terminal unit and the relay contacts may be used to key the loop in the usual double current mode. Care must be taken, of course, to reduce the current from 60mA to a value suitable for the type of relay used. When used in this way, it is necessary to bias the relay so that when no current is flowing through the coil it is biased towards one of the contacts, and when current does flow it is great enough to overcome this biasing and move the tongue across to the other contact. This biasing may be done in two ways. The most obvious is to mechanically bias the tongue by adjusting the biasing magnet on the relay. However, a more elegant way is available for relays having more than one coil. By passing a current of half the value of the keying current from the tu through another of these coils in such a way so that it opposes the motion of the keying current, the biasing will be much more accurately balanced. This is illustrated in **Fig 10.4**.

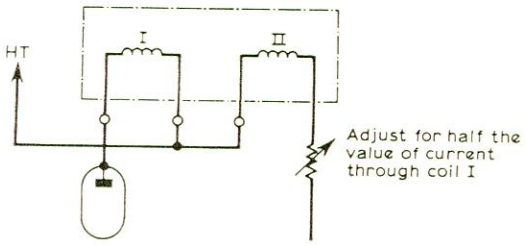


Fig 10.4. Electronic biasing of double coil polar relays.

Returning to the simple arrangement for transmitting and receiving rtty, as in **Fig 10.3**, the disadvantage of this system as it stands is that when transmitting, the receiver part of the teleprinter is not working, and is not producing local copy, and so the operator has no record of what he has sent. This does not sound such a bad disadvantage but in fact when transmitting on the air it seems "unnatural" to be transmitting "blind", and it is also impossible to correct errors that are sent as the transmitting operator will not know if he has sent one. Also, if the transmitting operator is interrupted in the middle of a sentence he will invariably forget where he has got to. This difficulty is best overcome by the use of a two-way switch and a high-speed relay, as shown in **Fig 10.5**. In this arrangement the transmitter is not keyed directly from the keyboard contacts but is keyed from the contacts of a polar relay, which in turn are keyed by the signal in the loop. Thus any signal in the loop may be used to key the transmitter. The relay used should have a low coil resistance if connected directly in the loop. But a high-resistance coil may be shunted with a resistor of the correct value to give the right amount of current through the relay coil. The two-way switch thus becomes a "Tx/Rx" switch, and may be conveniently one set of contacts on the rf transmitter on/off switch or relay. Moreover, if the switch is made into a multiway switch, any number of signal sources, or transmitters, may be switched into the loop, thus providing control of gear such as autos, a spare tu, or even the output of a tdms or a regenerative repeater. This idea can obviously be extended so that the loop is on a tu output when the station is on receive, and on a teleprinter keyboard or auto when on transmit.

It has been shown in the above paragraph how alternative transmitters, or "loop signal sources", may be controlled in a simple loop system. Next to be considered are the problems of connecting in more than one receiver. These different types of receiver might be two alternative printers, or a reperforator. A similar method may be used as in the case of the transmitters, ie by using a multiway switch and switching in the desired machine. However, a problem that does not arise with the transmitters is that it may be desired to switch in more than one receiver at a time. For example, when receiving off the air, it may be required to produce "hard copy" on the printer as well as a copy on tape for re-transmission, which will involve both a printer and a reperforator being connected in the loop at the same time. To do this there are two alternatives: they can be connected either in parallel or in series with each other.

If they are connected in series the inductance in the loop will be doubled. However, the total capacitance, connected in the case of the 7B under the base, will be reduced. If a high enough loop voltage is used the system may operate satisfactorily. However, if a low voltage is used the distortion introduced may be enough to cause misprinting on either or both of the machines. Should errors occur, then it is possible to eliminate them either by increasing the voltage of the loop supply, or by increasing the capacitance of the machines. Of these two, it is more convenient to increase the loop voltage, otherwise it would be necessary to switch in and out the capacitors depending on the number of machines in the loop.

If the two sets of coils are connected in parallel then the inductance is halved and the capacitance is doubled. In this case it is necessary to double the current in the loop since, when in parallel, only half the normal loop current flows in each coil. A method of conveniently switching in more than one receiver will be described later.

The position has now been reached when the simple loop circuit is not sufficient to control all the equipment that is found in many amateur shacks. Whereas it will work very well for a station with just one printer, and one tu, it is not possible conveniently to modify it to control a greater number of machines. It is thus proposed to describe a system that has been well tested for a number of years. Undoubtedly there are very much more sophisticated ways of controlling

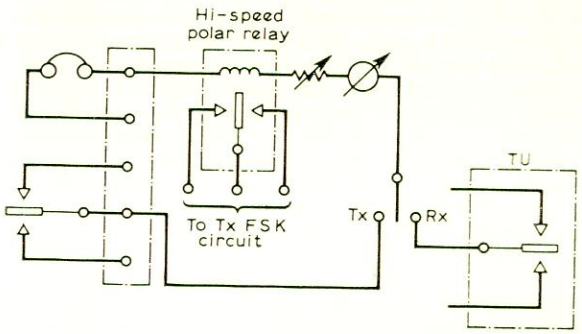


Fig 10.5. Arrangement of polar relay circuitry to enable production of local copy as well as on fsk signal.

rtty gear, but the system to be described, although being reasonably simple to set up, allows for a great deal of flexibility and also allows for virtually an unlimited amount of gear to be connected into it.

The system makes use of another set of contacts that are to be found on Creed machines. These are the transmit/receive contacts. These contacts should not be confused with the transmit/receive function associated with the station transmitter and receiver. They consist of a two-way single-pole switch; when the keyboard is inactive, ie not sending to line, the transmit/receive contacts will be in the receive position. When a key on the keyboard is depressed the contacts immediately change over to the transmit position and remain there until the character has been sent, and finally close while the 1·5 unit "stop" or mark pulse is being sent. The connections to these contacts are brought out separately to the plug of the printer and are easily wired to switch in the keyboard contacts automatically whenever a key is pressed.

Similar contacts exist on Creed autos and are only on the transmit position when a character is actually being transmitted to line. The method of using these contacts is illustrated in **Fig 10.6**. When no key is depressed on the keyboard, the loop current passes straight through the teleprinter keyboard via the receive contact and the tongue of the transmit-receive switch. However, as soon as a key is depressed the keyboard contacts are immediately connected to the line and the signal corresponding to the character depressed is sent down the line. After the signal has been sent to line, the t/r switch again goes into the receive position so that signals originating from further up the loop may now pass into the loop.

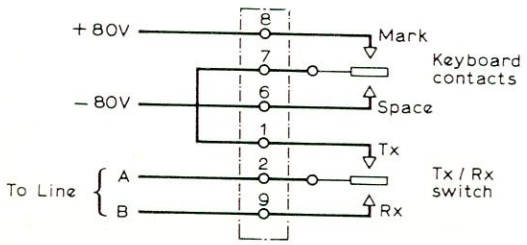


Fig 10.6. Circuitry of Creed 7B teleprinter showing send/receive contacts.

It is worth noting that the ± 80 voltages are not switched at all but remain permanently connected to the mark and space contacts. Exactly similar comments apply to the auto, and it is connected in exactly the same manner as the teleprinter board. On many commercial tus there is not a similar t/r switch performing the same function as the keyboard t/r switch. However, it is not necessary to have these t/r switches on every single transmitter in use, but the less that have then the more inflexible will the system become. On home-made equipment, it is quite possible to provide this t/r facility by putting a two-pole two-way switch in the place of the normal on/off one, thus providing a t/r switch. It would also be possible to modify other commercial tus by ganging another switch with the already existing one. These switches will not have exactly the same function as the ones on the keyboard and the auto, since the tu is continuously switched to line even though it is not actually transmitting a signal to line. The receiving coils are not switched at all and their termination will be described later.

The basis of the control system is shown in **Fig 10.7**. Polarity of the 80V used is that corresponding to a mark signal, and its choice is quite arbitrary so long as the standard is maintained throughout the system. The jack sockets used are of the "closed" variety, that is unless they have a plug inserted in them they remain closed circuit. The 80V is connected to the outer of the first jack socket, and the inner of this is connected to the outer of the next and so on. There is no limit to the number of jack sockets used, but enough should be incorporated to allow for all existing equipment to be plugged in simultaneously, plus a few spare. The resistor and the meter perform the same functions as before. The coils of electromagnets in printers, reperforators, etc are connected to a jack plug in such a sense that they are held in the mark condition when plugged into the loop. This is best determined by trial and error. The line marked "A" in **Fig 10.6** is connected to the tip or inner of a jack plug, and the line "B" is connected to the ring or outer of the plug. Now assuming that one transmitter is plugged in socket No 1 and a receiver in socket No 2, if the transmitter is not transmitting then its t/r switch will be on receive and current will flow down the loop from the 80V supply shown in **Fig 10.7**. As soon as the key is depressed on the transmitter the t/r switch will change over and the signal will pass down the line to the receiver. Note that if the receiver was in socket No 1 and the transmitter in socket No 2 then nothing sent by the transmitter will be copied by the receiver in socket No 1, but would be copied by receivers plugged in further down the line. Thus it is possible to control, to some extent, which receivers are controlled by which transmitters. However, it will be necessary to keep transmitters in the low numbers and receivers down the other end of the jack field. Thus if the receivers are arranged to operate in parallel it is possible to plug any transmitter or receiver into the loop, merely by inserting a single jack plug. This idea may easily be extended by using two or even more loops, ie duplicating the arrangement illustrated in **Fig 10.7**. Thus two sets of machines may be run simultaneously. If the tu in use does not have a t/r switch on it, it is quite possible to use it with this system merely by plugging in socket No. 1, since if any transmitter were to be plugged in a lower number socket any signal from it would not be passed to line. It should also be arranged for the tu to provide the necessary marking signal in the absence of any other signal in the loop.

Nothing has been mentioned about providing a relay in the loop to key the transmitter. It should be borne in mind that it is quite possible that there may be more than one transmitter available in the shack. For example, a two tone oscillator for use on vhf, and also a fsk'ed vfo for the hf bands. This problem may be overcome in two different ways.

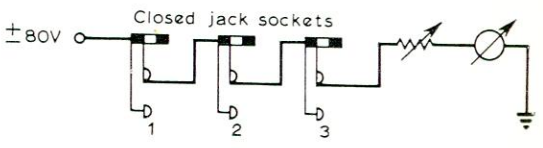


Fig 10.7. Basic teleprinter loop control circuitry.

The first is to connect the contacts of a polar relay to each circuit to be keyed, and then connect the coil of this relay (with suitable shunt resistor if necessary) as a receiver and to plug it into the loop as required. The alternative method is to connect a relay permanently across the loop, and bring its contacts out to a further jack, or similar socket, and then to plug into this socket the required rf transmitter. The advantage of the latter system is that it requires only one polar relay.

In some systems two separate loops are used and a transmitter keying relay is permanently connected into one of them, thus providing one "live" loop and one purely for local copy, or for receiving. This is a very convenient arrangement for providing "off-line" perforating. In this mode of operation, while a signal is being received a reply tape is being prepared in answer to the incoming traffic. In amateur practice this has very big advantages since most amateur typing speeds are fairly low. Thus, the tape is prepared while the incoming message is being received, and when the transmission is passed over the reply tape is fed into the auto and sent off automatically at full speed. This can be done with keyboard perforators such as the Creed type 44, but it is possible by using two loops to use one for receiving the incoming message and the other with the 7B keyboard and a reperforator to punch up the reply tape. In this way it is not necessary to leave the printer and an eye can be kept on it for drifting, QRM, etc.

Another example of the flexibility of this system is in the use of duplex. Most amateurs will be familiar with phone duplex, but differences arise when using duplex on rtty, since there are two ways of connecting up the machinery. In the first case, known as full duplex, no local copy is taken at the transmit end of the link and traffic may flow in both directions at the same time. This is equivalent to operating phone duplex with both operators talking at the same time. This may seem a little odd at first sight until it is realized that one or both of the stations may be sending a pre-punched tape, and it must be borne in mind that the operator's attention need not be on the incoming signal the whole time since the message is being written down for him to look at when he has a free moment. This full duplex system is the one most widely used on commercial circuits, since it provides greater traffic capacity and they are mostly concerned with transmitting prepunched tapes.

The other type of duplex is known as half duplex. In this case local copy is taken at the transmit end, and when a key is depressed the appropriate character appears both at the receive end and at the transmit end of the link. Thus it is not possible to transmit in both directions at once.

For full duplex two loops are used, one for receive, with tu and printer magnets plugged in, and the other for transmit, with keyboard and transmitting relay connected. If necessary it is possible to plug into the loops a reperforator and auto respectively. For half duplex one loop is used. The tu would be plugged into the first jack socket followed by the keyboard and auto if in use, and then the printer receiving magnets and reperforator if required. Thus it can be seen that virtually any combination can be set up by simply plugging in the appropriate jack plug.

If a regenerative repeater is required in the loop it may very easily be done with just one jack plug. The receive circuit, or input, to the regenerative repeater is connected to the tip of the jack plug and the transmitter, or output, of the repeater is connected to the tip of the plug. Thus when connected into the loop any signals appearing on lower numbered sockets will be applied to the input of the repeater and will be "cleaned up" and then passed to the rest of the loop sockets with higher numbers than the one that the repeater is plugged into. Also the outputs and inputs of tdms can be terminated with jack plugs and connected into the loops in a similar way.

Thus the basic loop system is formed. Note that modification or extension of this system may be necessary to cover particular circumstances, the main point of describing the system being to outline the basic principles behind any rtty loop system. Next to be described will be some of the control circuits that may be built round this, or similar, loop systems.

A little space will be devoted to the consideration of station lay-out. Experience shows that for the most part of rtty QSOs the operator is sitting in front of the main station teleprinter, and thus it is convenient to have the controls that are mostly used near this position. The most obvious is the t/r switch to control the rf transmitter and mute the receiver. But the operator will also have access to the tu on/off switch in order to prevent the printer racing under no signal conditions. He will also want to have easy access to the receiver tuning for correcting drift, etc on the incoming signal. He will also want to see easily any tuning indicator devices that are available in the shack. He will also want the loop control panel and other machinery, eg auto off-line perforator reasonably close at hand. And lastly, it would be convenient if the morse key were close at hand for the cw identification. It is also worth bearing in mind at this point that it is very desirable to have all rtty machinery on a separate table or bench from the receiver and transmitter, as the printer will cause vibrations which, if allowed to vibrate the receiver or transmitter, may cause frequency changes.

A very convenient way of mounting switches such as transmitter on/off switches is to fix a small aluminium panel on the frame of the keyboard, see **Fig 10.8**. On this panel miniature switches may be fixed, and this allows for very snappy "break in" operation of the transmitter. On this panel may also be mounted such indicators as the end of line indicators found on some 7Bs, or "transmitter on" warning light. If an automatic cw identification sender is available, its control switch would be conveniently mounted on this panel.

Consideration will now be given to the cw identification required by some licensing authorities before and after each rtty transmission. Most other countries in the world do not require this identification, with the notable exception of the United States, thus it is advantageous to have a slick cw identification system, especially when working continental stations. It should be stated at this point that it is quite legal to identify on phone, in fact G8 + 3s are obliged to identify on phone. However, on the hf bands identification is without exception always on cw. A simple way of doing this is merely to key the transmitter as for normal cw operation and arrange for a key down facility for use when transmitting rtty. This system is quite satisfactory, especially if the cw key is situated near to the printer. One refinement of this system is not to key the carrier on/off as in normal cw operation, but to use a very narrow shift, usually less than about 100Hz. If this is used the mark signal will remain inside the passband of the mark filter of the receiving tu, and prevent the printer from racing when the cw identification is sent.

There are surplus commercial units available which can be pressed into service as automatic cw identification senders, and it would not be difficult to make up one from scratch. One such unit that has been found available on the surplus market is a German machine that basically consists of a rotating disc with movable keys which can be slid in or out of the disc, thus making up the correct call sign. An illustration of this appears in **Fig 10.9**. The contacts "A" are connected to the transmitter cw key socket and are so arranged to be closed when the wheel has completed one cycle. The other contacts, marked "B" when closed, complete the supply circuit to the motor driving the wheel. On the panel beneath the teleprinter is mounted the cw identification switch, the function of which is to make a momentary connection across the contacts "B" until they close, whereupon the wheel rotates for one complete cycle and stops rotating when contacts "B" open again.

On the Creed 7B teleprinter there are several control functions, some of which are of use to the amateur and some of which are not. The first of these is the answer-back mechanism. The mechanical details of this device are dealt with elsewhere in this book; suffice it to say here that it is a mechanism fitted to the keyboard which can be set to send a predetermined string of characters from the keyboard contacts on receipt of a Figs D. signal. It is possible to set up one's own callsign on this mechanism and use it as the end of overs, etc. Most amateurs find, however, that it can be a nuisance when on receive since any Figs D will trigger the mechanism and, depending on the connection of the keyboard contacts into the system, may spoil the copy for the next 12 or so characters. Also, if one's own callsign is fitted to this device, and the transmitting operator sends a Figs D to trigger, the answer-back unit of the receiving teleprinter may cause loss of copy for a short time at the receiving end, with the result that the callsign will not be printed! (This system would, of course, work very well on full duplex.) Therefore, if using the answer-back unit to transmit one's own callsign it is better to find an alternative way to trigger it.

Another control circuit fitted to the 7B is the bell. This is not particularly useful in amateur operation because the operator is usually looking at the copy as it is coming in, whereas his commercial counterpart will very likely be in another room when an important message comes in on the printer. On the 7B the bell function is triggered by the reception of a Figs J, and in the 7B causes a pair of contacts to close, thus earthing one of the pins on the connector plug. When an electric bell and a battery are connected in series across this pin and earth, the bell will ring on reception of a Figs J signal.

A more useful control function to the amateur operator is a unit known as the end-of-line indicator. This is a small mechanism fitted to the keyboard of some surplus printers. Associated with it is a fairly large red lamp housing fitted on the immediate right of the keyboard. The function of this unit is to warn the operator when the end of a line is approaching. Whereas the operator can see by looking at the local copy whereabouts on a line he is, it is surprising how many times he will forget to look and start printing letter after letter at the end of the line. It is also most useful if no local copy is being taken for any reason (eg when operating on full duplex).

The last of the control mechanisms that may be found on a 7B, and indeed, on other makes of teleprinter, is the motor stop switch. This is quite a useful unit in amateur operation and is described in detail in chapter 2. Its function is to switch off the motor of the teleprinter when a signal has not been received for a given length of time. This time interval is adjustable, but is in the order of 1–2min. When a signal is received, the mechanism is tripped by the movement of the magnet armature and the motor restarts, and the printer is ready to receive the incoming traffic. It should be noted that while the motor is running up to speed the receive mechanism will not be able to receive signals as it is running at the wrong speed, and thus the first few letters of the message may be lost.

Fig 10.10 shows a complete rtty station set-up, including the receiver and transmitter connections. It must be borne in mind when connecting the audio output from the receiver to the tu, that most commercial tus use an audio input impedance of 600Ω, which is the normal line standard for

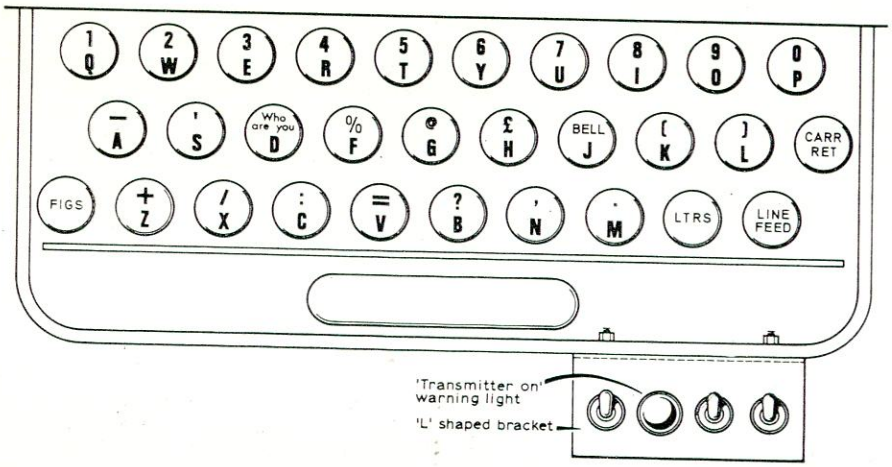


Fig 10.8. Control switches mounted on teleprinter keyboard.

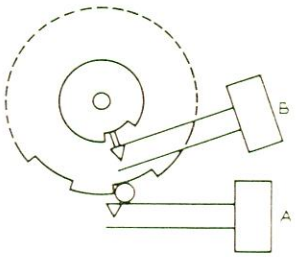


Fig 10.9. Diagram of an automatic cw identification sender.

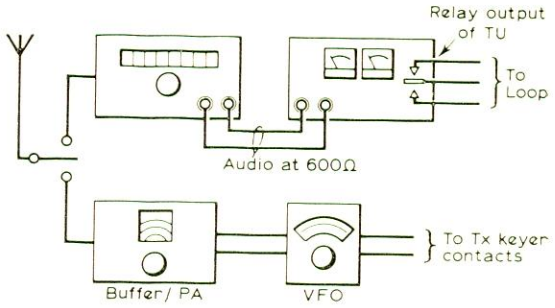


Fig 10.10. The diagram of a complete rtty station.

audio work. Thus if the extension loud speaker socket (normally 3Ω) is used to drive the tu the resulting mis-match will seriously affect the performance of the system. Many commercial receivers that are in use in amateur shacks today have 600Ω outputs already installed. Such receivers are AR88, B40, RA17, etc and these outputs are, of course, ideal for connecting to the tu. If, however, the receiver is not fitted with an output of suitable impedance a matching transformer must be used.

This chapter is intended to give the reader an idea of the principles involved in rtty station control. Some aspects have not been covered, such as KOX (keyboard operated TX) and Autostart. However, such circuits may easily be added to a well planned loop system, and a little thought in setting up the loop system will play dividends in operation of the station in the form of ease and flexibility of operation of the equipment. Thus the reader can use this chapter as a guide to designing his own control system to suit his own particular requirements.

CHAPTER 11

OPERATING PROCEDURES

IT is one thing to have a new rtty station, all ready to go on the air for the first time, but another thing actually to go about the business of communicating by rtty. CW operating technique is slightly different from that used on ssb, and on rtty, too, there are one or two things to be noted.

Your introduction to two-way rtty will be quick and trouble-free if, having chosen the right calling frequency in the chosen amateur band, you use:

exactly the same mark frequency as the station called,
the same frequency shift (850 or 170Hz),
the same shift polarity,
the same machine speed.

RTTY Frequencies

Selecting the right frequency in a band for calling is most important. RTTY is not permitted in the 160m band, but on most other bands amateur rtty operation is usually found on or near one spot frequency in the band. A newcomer tuning over almost any amateur band may easily imagine that it is well populated with rtty stations—but most of these are commercial rtty stations (some, regrettably, even in exclusively-amateur bands) or the harmonics of strong out-of-band commercials.

On 80M, regional habits tend to apply. Most UK amateurs use the 3,535–3,545kHz region, continentals use 3,800–3,900kHz, and the US stations are around 3,620kHz. On 40M, rtty can be found near 7,020 and 7,040kHz. The spot frequency habit is strongest on 20M and 15M, where nearly all rtty is within 10kHz of 14,090 and 21,090kHz. If there is a spot frequency on 10M, it is probably 28,090kHz, but this is affected by national band-plans and licensing restrictions.

Few regular rtty men ever think of tuning more than 10kHz or so away from these spot frequencies, so if you overlook this fact and settle down to call CQ on most other parts of the band, you may be in for a very long solo performance.

On the vhf bands there are rtty spot frequencies in the UK on 70·56, 144·6 and 432·6MHz (UK south) or 145·3 and 433·3MHz (UK north).

Zero-beat Operation

If you call CQ on the spot frequency, any reply will usually be in zero-beat with your mark frequency. Similarly, when calling a station heard on the frequency, be sure to zero-beat your own mark frequency with that of the other station. This is especially important should you need to call two stations already in contact—unless you zero-beat the mark frequency, their selective receivers may not pick you up at all. When several stations are operating in one net, using the same mark frequency will obviously obviate much retuning as the various stations transmit.

Frequency Shift

Be sure that your shift is set to either 850 or 170Hz exactly —using, if possible, the same shift as the station called. The use of phase-shift type rtty shift monitors of the G8LT or W0HZR type will enable both your own and incoming shifts to be quickly checked.

With ssb equipment being used more and more on rtty, the restrictions imposed by the filters used in this equipment are helping to increase the popularity of 170Hz shift, and as an added bonus the stability of ssb equipment enables narrow shift transmission to be used without the nuisance of frequent retuning. With narrow shift, too, receivers can use more selectivity to receive signals under bad interference conditions.

If the other station is using a linear discriminator type of demodulator (many surplus TUs are of this type), they will receive rtty with any shift between 1,000 and about 200Hz without much difficulty. In this case it will not matter much if your shift is not accurately set to either 850 or 170Hz. However, many amateurs use demodulators with sharply-tuned high-Q toroid filters, peaked for 850 or 170Hz shift, and they may not receive you well if your shift is not correct.

Correct Shift Polarity

To "correct shift" must be added "correct shift polarity". It is standard amateur practice to put the mark signal on the higher of the two radio frequencies radiated. Some ssb transmitters, however, do not have a choice of sidebands on any one band, and may not be able to print "the right way up". Most demodulators have reversal switches to cope with any upside-down shifts received.

RYRYRY signals are soon recognizable by ear, but if they print out SYSYSY you are printing upside-down, and the polarity switch needs to be thrown over. Here again a cathode-ray rtty shift monitor is invaluable: the mark frequency is easy to spot since a rtty signal spends more time on mark than on space—especially between letters, words and sentences—and the polarity of the signal will immediately be obvious.

AFSK is not used with am/cw-type hf transmitters on the 80–10M bands—these need fsk—but either fsk or afsk can be used with a ssb transmitter on these hf bands. On vhf, however, afsk can be used with an am/cw-type transmitter, though it is not generally very effective for anything beyond fairly local working. For serious work on vhf, fsk is again to be preferred.

Correct Speed

One of the basic requirements in rtty is correct motor speed on all machines, whether this is 45·45 or 50 bauds. Governor contacts on governed motors should be regularly

burnished, and the speed checked by fork or other means to ensure correct speed.

Two amateur speeds are used: 45·45 and 50 bauds. 50 bauds is used within the UK, mainly on 80m and on the vhf bands; 45·45 bauds is used by most other amateurs outside the UK. In consequence, the UK amateur with no interest in dx working sticks to 50 bauds or, if he also uses the dx bands, will have two governors, or a specially made dual-speed governor, allowing 45·45 or 50 bauds to be used at will.

The use of 50 bauds in the UK and 45·45 bauds in the USA was, of course, determined by the speed of the commercial or military teleprinters available on their respective surplus markets. In the UK 50 bauds working was the norm in the British Post Office and in the Services. In the USA (where the bulk of the amateur rtty population lives) 45·45 bauds was used not only because the machines were usually fixed-speed with synchronous motors, but also because the amateur speed was restricted to 45·45 within fairly close limits by the FCC. With the arrival of newer rtty machines on the US amateur market, however, higher speeds are becoming available and the FCC has been asked to modify the restrictions on speed.

A newcomer to rtty may well wonder—if he types very slowly by the usual "hunt and peck" method, and is unlikely to be able to type fast enough to use the full capabilities of 45·45 bauds let alone 50 bauds—"why all the fuss about speeds?" However, higher transmitting speeds are not related to one's keyboard typing speed. The keen rtty man tends to transfer many of his transmissions—certainly all repetitive calls like CQ—on to perforated tape, so that tape machines can take over the work of the keyboard, and it is with such tape machines that the true benefits of faster speeds are realized.

CW Identification

In the UK and in some other countries it is still necessary to send your own station callsign on cw or phone immediately before and after an rtty transmission. This need only be sent once, as DE G4XXX.

If sent in cw (which is more usual) it is often sent as a very narrow shift transmission, within the passband of the mark channel filter, and in this way does not make the other man's printer race on long space signals. The amount of shift here need be no more than 50Hz, and can be produced by another potentiometer in your fsk circuit controlled by the cw hand key.

Some overseas amateurs do not send cw identifications, so be prepared for immediate rtty.

Using the Keyboard Correctly

There is more to using the teleprinter keyboard than typing on a commercial typewriter, and it is obviously better to do it the correct way right from the start.

For one thing, you have a double responsibility; you are also indirectly controlling the teleprinter at the other end. Not only do you have to ensure that the other man's machine is properly prepared to start printing your transmission, you also want to help it to correct printing errors caused by static, interference or distortion over the transmission path.

When you are about to start sending, you have no idea where the other man's paper carriage is—so ensure that it is at the start of a fresh line by starting every transmission with:

CAR-RET CAR-RET LINE-FEED LTRS LTRS

As it is so easy to recognize by ear, send a burst of RYRYRY to help the other man check his tuning, followed by:

CR CR LF LTRS LTRS

and start sending the callsign of the station being called. CR is usually sent twice to ensure that at least one is correctly received, and that slow-moving carriages get there before LF and LTRS signals are through.

At the end of every line of print send:

CR CR LF LTRS LTRS

(unless, of course, you wanted to open the new line in FIGS, when you would hit FIGS FIGS instead of LTRS LTRS).

When you reach the end of your transmission—and this is a good moment to urge you to keep your transmissions short and snappy in case interference has wiped out your signal—do not leave the other's man's paper carriage stuck half-way down the line, send:

K K K CR CR LF LF LTRS LTRS

and go over to him.

When conditions are really bad, it is useful to the other man to send extra LTRS signals (or FIGS, if appropriate) at intervals along the line of print.

Some overseas amateurs hit the "bell" key three times just before they sign, as a signal to the other man to return to his keyboard. However, US keyboards usually have their "bell" signal on FIGS S and their signal "bell" is often within the printer, and mechanically rung. English keyboards have "bell" on FIGS J, and receiving a "bell" signal merely closes a pair of switch contacts within the printer to actuate an external electric bell circuit. This may explain why the "bell" signal and its uses are often ignored in the UK. It will also explain why when an American teleprinter sends "bell" signals an English printer prints out ' ' '.

Typical CQ Call

(On cw) DE G4ZZZ (then switch to rtty)
CR CR LF LTRS LTRS RYRYRYRYRY CR CR LF LTRS LTRS
CQ CQ CQ DE G4ZZZ G4ZZZ G4ZZZ (repeated several times)
AR AR CR CR LF LF LTRS LTRS
(Then on cw) DE G4ZZZ (and switch over to receive).

Typical Contact

(On cw) DE G4ZZZ (then switch to rtty)
CR CR LF LTRS LTRS
G2AAA G2AAA G2AAA DE G4ZZZ G4ZZZ G4ZZZ
CR CR LF LTRS LTRS (and you are off!).
At the end of every line send the usual CR CR LF LTRS LTRS.
At the end of the transmission send:
G2AAA DE G4ZZZ K K K CR CR LF LTRS LTRS
(On cw) DE G4ZZZ (and switch to receive).

Be prepared to find that either your receiver or the other man's transmitter may have drifted slightly, necessitating slight retuning of the receiver. Here once again a rtty shift monitor gives an immediate indication of correct tuning.

Avoid the bad habit of pressing the space bar repeatedly while thinking what to say next—thus making the other man's carriage inch uselessly down the line. If you feel compelled to punch a key while you think, punch LTRS.

If CR CR LF LTRS LTRS is sent at the end of every line of print it will soon become a subconscious and efficient habit, and will keep misprints due to static, interference and distortion down to a minimum.

Do not worry about the slowness of your typing speed if you are new to the keyboard. RTTY is not a rat-race as yet and most rtty men are tolerant, friendly people. Most rtty transmissions are sent out in normal English, just as if a letter was being written, but making use here and there of the popular amateur abbreviations if they save time. Long monologues on rtty are as irritating as they are on other modes, and a contact moves along much faster if composed of several short transmissions and not of a few long ones. Break-in working is also good practice, as long as the customary periodic station identification is observed.

Auto start

When you transmit by rtty you can operate by remote control various mechanical functions in another teleprinter that is possibly thousands of miles away. Just as easily, you can control other equipment in his shack.

One form of remote control is known as "bell auto". When you press the "bell" key on your keyboard, it causes contacts to close in the other man's teleprinter to complete his bell ringing circuit. Just as easily, these "bell" contacts can be used for controlling other circuits—such as send/receive switching.

Continuous monitoring of an rtty net frequency must inevitably result in vast amounts of paper being wasted, usually with only a small percentage of good copy. Even with just the receiver and demodulator running continuously, and the printer coming on only when rtty signals are present, much of the copy will be of no interest, and more than one station on the net frequency at the same time will cause garbling and more wasted paper. Teleprinters such as the Teletype Model 28 fitted with automatic carriage return and line feed are very useful in unattended autostart operation.

An improvement would be to control all the equipment by a time-switch which turns receiver and demodulator on at desired times for a fixed period, switching off again should no rtty be heard, or when any received rtty ends. Receivers with appreciable warm-up drift are not suitable for this method of operation obviously.

More sophisticated equipment enables individual stations to be called up and actuated automatically by the use of different calling tones, using the appropriate highly selective filters at the receiving end.

The simpler forms of autostart can be brought into action by cw or phone signals on the frequency, but this can be avoided by a method that takes account of the "duty time" of the received signal. CW is usually less than 50 per cent key-down "duty time", and phone is usually between 20–30 per cent. RTTY, however, is 100 per cent "duty time" and it is therefore possible to design an autostart circuit that allows only a high "duty time" signal to start up the printer, thus ignoring cw and phone. Such a circuit can be adjusted to ignore also the weaker rtty signals that would not have resulted in good copy anyway.

With any form of autostart that involves unattended operation it is very desirable that every separate item of equipment is individually and realistically fused. It must be remembered that some items of equipment were never designed for continuous operation without risk of overheating, but it is sometimes possible to provide additional cooling.

Plenty of fuses and sensible "fail-safe" precautions should ensure that there is no trouble in the operator's absence.

RTTY Contests

Contests do not appeal to everyone, but most people can improve both their stations and their operating techniques by copying the methods of successful contestants.

Success in rtty contests can be attributed to the same grand efforts that are a prelude to contests in any other mode: lf, hf, or vhf; cw, ssb, or whatever the style. No contest is won without a deal of thought and consideration for the requirements of each individual type of contest. As with other modes, each group of rtty contest organizers has its own ideas as to what it wants to bring out, and rules and scoring systems are designed to this end. What seems to be the best method of awarding points to contestants to one organizer is not always agreeable to another organizer, and therefore methods of scoring differ. It is essential that, before entering the fray, the rules and requirements are fully understood. One can then plan the method of attack and labour not in vain, one hopes.

Whatever the method of attack (and the top men will tend to conform to much the same pattern) and however well it is planned, the results will only be as good as the station and the technical (and typing) ability of the man behind it. The main considerations—which can be applied to contesting generally—are as follows:

1. The aerial.
2. The receiver.
3. The transmitter.
4. Other rtty equipment.
5. Own station interference.
6. Equipment accessibility.
7. Operating techniques.
8. Log-keeping and non-operating periods.

1. The Aerial

All things being equal (and they never are) it is fair to say that the man with the best aerial stands the best chance of winning a contest. Since all things are not equal, it is essential that the utmost be derived from every single item that plays a part in the performance of the station.

With the exception of vhf contests, rtty contests are mostly five-band affairs. Therefore the optimum radiation ability on five bands is of great importance. Starting at the high end of the spectrum, 10M through to 20M, there are few stations who can afford separate steerable rhombics for each band. Pieces of wire can be made to do good work when you have nothing better, but however clever one may be at charming the rf out of a dipole or ground-plane, competition with these devices is one-sided when one is trying to out-perform the man with his three-element beam launching rf from 60ft.

It follows then that the hf band aerial should conform to certain minimum requirements, namely, have appreciable gain over a dipole, be fully rotatable, have the best-obtainable front-to-back ratio, and last but certainly not least, exhibit low-angle radiation. These requirements in a three-band array suggest two possibilities for most of us:

(*a*) a trapped three-element tri-bander,

(*b*) a tri-band quad.

Both of these arrays are most useful and both are a

compromise to some small degree. The trap beam can be useful on three bands but has its inherent losses in the loading coils, yet to some may look better than the box configuration of the quad. On the other hand, while not everyone likes the look of the quad, it has less "wing span" than the other. There ends the compromise.

Past experience proves that, power for power and at heights of 30–40ft, the quad leads the trap beam on long distance contacts usually by one "S" point, sometimes more, rarely less. At greater heights—60–70ft or more—the difference between the two tri-banders may be a little less noticeable, and both aerials perform even better, but not all amateurs have masts at 60 and 70ft. When such heights are out of the question for the tri-bander, the cubical quad array is generally accepted as the best and most potent performer when correctly tuned.

The lf aerial. For the lf bands—40M and 80M—little can be done by the amateur to beam in any particular direction. Heights normally used at these frequencies are small in terms of electrical wavelength, and horizontally-polarized aerials even at a half wavelength generally tend to produce high-angle radiation.

Low-angle radiation is what the dx man likes to know about, and most vertical aerials of a quarter-wavelength up to five-eighths wavelength in height produce the long-distance contacts. It has been found during contest conditions that on 40M the W, XE, and South American stations have been heard or worked on a quarter-wave vertical, but not heard at the same signal strength on another aerial which was half-vertical and half-horizontal. In contests, therefore, the vertical aerial is favoured for its all-round low-angle radiation.

Whichever aerial has been decided upon per band, the ability to select the appropriate aerial instantly is important. Precious seconds—or minutes—lost in changing from one aerial to another can be ill-afforded during a contest. Apart from quick switching, a good coaxial switch of the same characteristic impedance as the feed line is invaluable. Use of switching methods other than a correctly designed coaxial device will easily upset the vswr on the feeder. Where a single wire has to be pressed into multi-band service, tuning settings on the matching device should be noted for the respective bands, and logged beforehand, so that contest time is not wasted looking for a satisfactory match.

2. The Receiver

Selectivity. The development of receivers in the ssb field has brought benefits not only to the phone operator, but also to rtty and cw men as well. Prior to the snowballing of ssb, most communication receivers had funnel-shaped responses and behaved in a like manner. While the ssb operator is confronted with adjacent channel interference and solves his problem by the use of sharp mechanical or other filters, the rtty man has the same problem, and happily the same solutions apply. Adjacent channel interference affects ssb, rtty and cw modes in similar fashion, and can be kept to a minimum by the use of sharp and steep-sided filters. In contest work good adjacent channel discrimination is of great importance on highly congested frequencies, and should be obtained in i.f. stages prior to demodulation.

Sensitivity. This should be the maximum signal-to-noise ratio possible while avoiding cross modulation effects from very strong local stations who may be running very high power into very efficient aerials at very respectable heights. Receiver sensitivity should be adjustable for transmitter monitoring.

Stability. The use of narrow shift (170Hz) is common under contest conditions and requires receiver oscillator stability of a high order. Since some receivers are capable of high selectivity, oscillator stability must be on a par if a station being received is to remain in tune for any period.

Ease of operation. "Amateur bands only" receivers score in ease of operation, where band-switching is single-switch control, and band-edge calibration coincides at the same point on the receiver dial. Hence 14,090, 21,090 and 28,090-kHz are there immediately at the movement of the band-switch. Some transceivers may be similarly designed. Minimum receiver adjustment during operation is very desirable.

3. The Transmitter

For the transmitter the requirements are basically the same as the receiver with regard to band-switching and stability, etc, though ease of operation can rarely be as simple as that of the receiver. However, simplicity of operation is desirable when the contest operator may wish to change rapidly to another band to work another station possibly considered to be something of a rarity. At the time when this is being written, not all continents are in good supply during a contest and it pays to be able to capture them quickly when the opportunity presents itself.

Single-switch control is ideal although not always possible since there are rf-producing amplifiers to be tuned. Again, probably the most convenient type of transmitter for a contest is the transceiver, with usually a linear PA.

Reliability over long periods of operation is essential. Any power supply that may heat up excessively because of long periods of operation can prove embarrassing in the middle of an important contact when some piece of equipment breaks down. Although the power supply is mentioned here, the same conditions apply any link in the chain. PA valves run hot at maximum continuous ratings and a PA valve able to handle larger power inputs than normally required and run well within its limits, is less likely to get overheated and subsequently fail.

Whatever form the transmitter takes, simplicity in operation pays off. Complete control of the transmitter, receiver muting and aerial changeover should be with a single switch close to the teleprinter.

4. Other rtty Equipment

All equipment must be fully serviceable before the contest starts. An hour or two spent checking and servicing mechanical equipment—teleprinter, tape machines, etc—prior to the contest will usually repay with trouble-free operation for the entire 36–48h of almost continuous use. Time spent in cleaning, lubrication, checking spring tensions, etc is an investment, never a waste. However, it is wise to do the initial check some two or three weeks at least in advanace, particularly if the equipment has been left standing and unused for some time. If there is anything seriously wrong and is discovered, there is time to find a replacement part. A quick check on power supply voltages on and off load may also reveal the occasional future fault, and can then be remedied. One thing is sure: if there is a weakness in any equipment, a long contest will certainly bring it to your notice.

5. Own Station Interference

A lot can be said on the problems of own station interference from governors, motors and so on. Let it suffice to say that this should be checked well in advance and the appropriate measures taken so that the receiver hears little or nothing of any rotating machinery in the station.

6. Equipment Accessibility

All equipment should be made easily accessible for repair or adjustment in any event of failure. To this end, it is a good thing to ensure that items of equipment not required in the contest are cleared from the station completely, or from positions affecting access to essential equipment.

All operating equipment with metering and switching should be within easy reach and sight of the operating position. A very convenient place for the log is on the message holder found on most teleprinters. When things are really moving, the log entries grow rapidly. If a small area of bench or shelf is reserved for the odd cup of tea or coffee, it should be out of elbow reach to avoid accidents.

7. Operating Techniques

If the operator has tape equipment available, a good deal of time and energy can be conserved by spending a little time before the contest preparing a number of tapes for various purposes.

Probably the most used tape in a contest is the CQ tape. Two of these should be made, three if your auto-transmitter tends to be a bit hard on tape.

Bearing in mind that many people are continuously scanning the frequencies carefully for "the one I haven't worked on this band", CQ tapes need not be long affairs. Two or three lines of CQ CQ CQ DE G3XXX (callsign continued to the end of the line) are all that is required, and longer than that only serves to frustrate the man printing you with "landline" copy, and sitting there with bated breath.

If you have difficulty in getting your fingers round "QRZ", a small QRZ DE G3XXX QRZ DE G3XXX QRZ DE G3XXX tape can be handy.

If you intend to save more time and make it look as though you are a well-seasoned operator the tape perforator will be instantly available, waiting to punch out the call-sign of the operator calling "CQ Contest" and hoping that some exotic dx station is going to appear on his printer alone. The reply to the call made with the help of the perforator will be impressive and conducive to good operating procedure.

For some operators another time-saving tape is the one that has almost the entire contact already on it. All it needs is to stop the auto-transmitter occasionally to fill in manually from the teleprinter keyboard the interesting bits the other man needs for his log—things like serial number, time, RST, zone (if required by the rules), and your country. The serious contest man will not be interested to know your name, or to know that the sun is shining. Contest contacts must be brief and to the point, then, when the message has been confirmed both ways, careful tuning is resumed.

While it is sometimes necessary to call CQ now and again to let others know that you are around, often more can be netted by careful listening and by printing all and sundry. By listening more carefully than anyone else, you may be able to spot a fresh station that no one else has yet heard. When this happens, you sit tight with your three-by-three (his call three times DE your call three times) tape ready in the auto-transmitter gate, waiting for him to finish.

The technique used in phone contests of calling off the other man's frequency is not used in rtty, and would only serve to clutter up the already jam-packed channels in use. Besides, most operators, having called on some frequency, will invariably sit back and wait for one or more of the stations to print intelligibly. It is ironic that often the last one to vacate the channel has an S9 signal and takes long enough printing your call-sign to have had three contest contacts in the time. You give him the information in double-quick time, and get frustrated while he spends the rest of the contest giving you your report and telling you that he hopes to see you again on the other bands.

A final point: tuning transmitters up on the band, instead of into a dummy load, or radiating keying clicks, are not only undesirable but illegal, and should be avoided at all costs.

8. Log-keeping and Non-operating Periods

The rules of a contest must be carefully read and understood before starting. They often differ in many ways: log requirements, methods of scoring, time off during the contest (non-operating periods), message contents, etc.

Logs usually contain: serial number, RST (given), and time. In most cases, the band in use goes at the top of the log, with all the contacts on a particular band entered on one or two separate log sheets. The log sheet also contains all the information received from the other station: serial number, time, call-sign, RST, and zone if required by the rules.

When submitting contest logs it is of great help to the judges in their enormous task of evaluation if all entries are made clearly on a separate duplicate sheet, and the scores carefully worked out and clearly indicated on a score sheet, with the countries listed by bands.

Lastly, one should be very careful to ensure that one does not spend too much time in the contest, and that the specified periods of non-operation have been observed. When you take time off is usually up to you, but it is often in the form of a minimum period of two hours rest at any one time, totalling twelve hours or so. It pays to remember the rules.

CHAPTER 12

GLOSSARY OF COMMERCIAL EQUIPMENT

Creed & Co. Ltd

3X: Tape printer widely used in pre-war P.O. telegrams service.

6S/3 (1B), 6S/5 (2D), 6S/6M: Tape readers (auto-transmitters) for $\frac{11}{16}$in tape. 6S/6M has magnetic clutch—stops when tape out.

7A: Page Printer with keyboard, sprocket or friction-feed paper carriage, ac or dc motor. Transmitting cam angles = $7\frac{1}{2}$ units; receiving cam angles = 7 units, cadence speed on both transmit and receive is 66 words/min. Will operate with 7A and 7B machines.

7B: Similar to above machine, occasionally with tape-printing unit fitted in place of paper carriage. Transmitting cam angles = $7\frac{1}{2}$ units; receiving cam angles = $6\frac{1}{2}$ units; cadence speed on transmit is 66 words/min, and on receive is 66 or 72 words/min. Will operate with 7A, 7B, 7C machines.

7C: As above machines. Transmitting cam angles = 7 units, receiving cam angles = $6\frac{1}{2}$ units, cadence speed on transmit = 72 words/min, and 66 or 72 words/min on receive. Will operate with 7B and 7C machines and with most others working at 50 bauds.

7D: As model 7B, but with 33-way plug.

7E: Similar to model 7B but fitted with overlap camshaft. This results in each character being printed immediately after a key has been pressed (not one behind as on model 7B) and also gives a minimum margin of $\pm$ 40 per cent.

7B/RP: Page-printer as 7B, but with reperforator unit for $\frac{11}{16}$in tape fitted at left-hand side of keyboard and tape-reel outside cover on right-hand side of machine.

7P/N4: Off-line keyboard tape perforator for $\frac{11}{16}$in tape, ac motor ungoverned (Model 45). Occasionally found with tape reader fitted on left-hand side and governed motor.

7TR, 7TR/B/2, 7TR/3: Non-printing reperforator for $\frac{11}{16}$in tape. Selector mechanism similar to 7B. 7TR/B/2 has 24V dc motor. 7TR/3 has two tape reels and can punch two tapes simultaneously.

8B: Receiving-only version of 7B page-printer. No keyboard.

25: Five-, six-, seven- or eight wire tape punch used in data processing.

35: High-speed tape reader—up to 40 characters/sec in either direction, yet stops within one character pitch. Five-level and eight-level versions (the latter adjustable to six- and seven-level). Both models can be adjusted to take edge-punched cards.

47: Tape printer (47/R: receiving-only). (GPO 11).

54: Page-printer developed out of 7B, which it resembles, and with base slightly tilted towards operator. Can be fitted with perforator unit and tape reel (inside cover) at left-hand side of keyboard.

71: Three-gang multiple tape reader with three independent tape heads for $\frac{11}{16}$in tape with common base and motor.

72: Similar to 71 but with three number transmitting heads for message identification facilities with 71.

74: Combines 71 and 72 to give one number, and two message, tape reader heads.

75: Compact page-printer with or without keyboard. Fixed platen and moving typehead. May be fitted with reperforator, tape reader, dual-speed gearbox, combined CR/LF key, automatic CR/LF, two-colour printing.

75PR: Printing reperforator developed from 75 printer. Prints and produces fully-punched $\frac{11}{16}$in tape (which can therefore also be read on photoelectric tape readers).

85: Similar to 7B printer (with or without keyboard) but with $\frac{11}{16}$in tape perforating and printing attachment instead of paper carriage. Chadless tape, printed over.

86: As 85, but uses $\frac{7}{8}$in tape with printed record below fully-punched holes.

92: Electro-magnetically operated tape reader in five-, six-, seven- and eight-level versions largely used in data processing.

444: Page-printer of modern design (1967) available with built-in punch and reader, optional "stunt box" for remote control operations. Speed up to 75 bauds.

/CTK: Commercial typewriter type keyboard for 7B series printers.

/N3 and /N4 Keyboards: Three- and four-bank keyboards of shift-lock design, superseding older "M"-type keyboard.

Booth-Wilmot

44: Solenoid-operated off-line keyboard perforator for $\frac{11}{16}$in tape.

Lorenz

DRELO 554E: Receiving-only printing reperforator.

DRELO 554S: Send/receive printing reperforator.

LO-15: Page-printer, design similar to Teletype Model 15.

Siemens

T-100: Page-printer.

100S: Page-printer that can be used like a typewriter due to the provision of automatic 'ltrs" and "figs" case shifts and storage to enable typing speeds higher than transmission speed.

Kleinschmidt

AN/FGC-20: Page-printer.

AN/FGC-25: Composite set with TT-117/FG, TT-179/FG, FN-65/FG table.

TT-4/G: Portable, lightweight page-printer.

TT-76/GGC: Reperforator and tape reader in lightweight, portable form with tubular legs which fit into the printer base.
TT-107/FG: Reperforator.
TT-117/FG: Page-printer.
TT-179/FG: Reperforator and tape reader.

Teletype Corporation

14: Tape machines in several forms: a $\frac{3}{8}$in tape printer, a printing reperforator ($\frac{11}{16}$in chadless), with and without keyboard. The printing reperforator also comes in a square box as a receiving-only model, and this also appears as a non-printing reperforator.
14-TD: Transmitter-distributor (tape reader) for $\frac{11}{16}$in tape.
15: Page-printer with or without keyboard. Paper is stationary while the type bars move down the line. (Military versions: TG-7-A, TG-7-B.)
19: Composite set of Model 15 page-printer with keyboard, $\frac{11}{16}$in tape perforator, and Model 14-TD tape reader, mounted on special table containing power supplies and interconnections. A character counter is fitted to the perforator unit so that messages can be punched on tape suitable for reception on page-printers, while the Model 15 is receiving another message. A Model 14 printing or non-printing reperforator is sometimes included in the set. (Military versions: TT-7/FG, TT-8/FG).
26: Page-printer, rarely seen in Europe. Prints from movable pallets carried in a typewheel.
28KSR: Page-printer with or without keyboard, in table or floor console. Gears available for 45·45, 50 and 75 bauds operation. Synchronous or governed 115V motors. Wide range of accessories and functions, such as automatic CR and LF.
28ASR: Page-printer fitted with tape perforator and reader. A built-in "stunt box" can be arranged to actuate equipment remote from the printer by the reception of one specific character, or several characters in correct sequence. The Tape Punch can be: non-printing perforator (LPE) printing perforator (LTPE), non-printing reperforator (LRPE) or printing reperforator (LPR). The Tape Reader can be: fixed head single-contact TD similar to Model 14 TD (LXD), fixed head multi-contact TD offering series output or parallel (five-wire) output (LBXD), pivoted head multi-contact TD—the pivoted head moves along the tape and reads/transmits the last character punched (LAXD), pivoted and fixed head multi-contact TD—has one pivoted head inside the 28 cabinet to read tape from the 28's tape punch, with another head (like LXD) outside cabinet to read any other tape (LCXD). Model 28 has a wide range of accessories and options, and is used in communications and in data processing.
31A: Lightweight, portable $\frac{5}{32}$in tape printer in aluminium case; ac/dc motor. Has end-of-line indicator so that its tape can be received on a page-printer.
32: Modern page-printer with or without keyboard in table or floor console models available as 32RO (receiving-only), 32KSR (keyboard send/receive) or 32ASR (automatic send/receive with built-in tape reader and perforator).
33: Eight-level version of 32 available in RO, KSR and ASR models.
35: Heavy-duty versatile printer for communications and data processing.
FRXD: Combined printing or non-printing reperforator and tape reader. When tape goes taut, tape reader head moves up the tape towards reperforator punch, reading up to the last character punched.

IDENTIFICATION OF AMERICAN ELECTRONIC EQUIPMENT NUMBERS

American Electronic Equipment numbers are usually in the form AN-URA-8. The AN means Army/Navy, URA identifies the type of equipment and the 8 is a model number. The middle three letters may be further broken down in the following manner:

First Letter
A: Airborne
B: Submarine
F: Fixed
G: Ground
M: Ground mobile
U: General utility.

Second Letter
C: Carrier (wire)
G: Telegraph or teleprinter
R: Radio.

Third letter
A: Auxilliary assemblies (not complete sets)
C: Communications (receiving and transmitting)
M: Maintenance and test equipment
R: Receiving
T: Transmitting.

CHAPTER 13

TERMINOLOGY

afsk: audio frequency shift keying.

atc: Automatic threshold corrector.

Automatic transmitter: An instrument for converting a perforated tape into equivalent electrical impulses suitable for operating a teleprinter etc.

Answer-back: See "Who are you?"

Baud: The telegraphic speed of working, in bauds, is equal to the reciprocal of the shortest signal elements in 1s.

Bellcrank: A crank the arms of which are at right angles.

Bias: A force exerted on a mechanical or electrical device or circuit which tends to hold the device or circuit in a given condition.

Bias distortion: Distortion due to either the marking or spacing elements of the signals being lengthened due to asymmetry in the transmitting or receiving apparatus.

Cadence speed: The speed of transmission normally expressed in words per minute which is obtained when the signal elements comfirming the code for each character are continuously transmitted at the specified telegraph speed in bauds.

Two teleprinters having the same telegraph baud speed do not necessarily have the same cadence speed: for a telegraph baud speed of 50 bauds, using 7-unit transmission, the cadence speed is 71·4 words/min; for a baud speed of 50 bauds, using 7½-unit transmission the cadence speed is 66·6 words/min.

Cam: The grooved, recessed, or projecting part of a wheel or spindle adapted to convert rotary motion into backwards and forward or reciprocating motion.

Carriage return: The function that causes the paper carriage to return to its extreme right-hand position, ie for the next character to be printed at the left-hand side of the page. On machines not having a moving paper carriage the function causes the type basket, type wheel, etc to return to the extreme left-hand position.

Carrier telegraphy: Carrier transmission of telegraph signals.

Case: Synonymous with shift.

Chadless tape: A tape similar to perforated tape except that the holes are not cut clean, the paper being not completely cut out.

Character: A character is a letter of the alphabet, numeral or other symbol transmitted from the keyboard and printed on paper by the receiver.

Characteristic distortion: The distortion consistently with any given series or combination of signal elements.

Circuit: A number of conductors connected together for the purpose of carrying a current. When they form a closed path through which a current can circulate, the circuit is said to be closed; when the path is not closed the circuit is said to be open. Also a channel terminated at each end for traffic use.

Closed-circuit system: In telegraphy. A system in which current flows continuously in the circuit and in which the current is subject to control by any station for signalling purposes.

Combination: A particular arrangement of code elements.

Crank: A lever the arms of which are at an angle; used to transmit motion from one plane or direction to another.

Crosshead: A reciprocating block, sliding between, or on, guides.

dBm: Abbreviation for decibels relative to 1mW.

Direct circuit: In telegraphy. A circuit in which the currents transmitted operate the distant signalling instrument without the intervention of a relay.

Direct-current telegraphy: A form of telegraphy in which, in order to form the transmitted signals, direct current is supplied to the line and is controlled by the transmitting apparatus.

Double-current system: A telegraph system in which signals are transmitted by reversing a current that is normally on the line during transmission.

D.T.C.: Decision Threshold Computer.

Duplex: The general term applied to methods of telegraph working by which messages may be sent simultaneously in each direction over a circuit.

Eccentric: The circular parts of a wheel on spindle whose axis are not placed centrally; used for changing rotary into backwards and forwards motion.

End-of-line indicator: A mechanism attached to the transmitter of a teleprinter, etc to provide a visual or aural indication when a specific number of keys have been depressed after the carriage return key. This device is used as a warning to depress the carriage return key in cases where there is no local record or only a tape record at the transmitting end and the receiving machine is a page machine.

Extra: A mis-selected element of a code combination in which a spacing condition has been replaced by a marking condition.

Failure: A mis-selected element of a code combination in which a marking condition has been replaced by a spacing condition.

Figure shift: That function which causes the receiving and printing mechanisms to switch over from alphabetical characters to figures.

Filter: A device for the selective transmissions of different frequencies of electromagnetic, electromechanical and electric-acoustic vibrations.

Fortuitous distortion: Distortion due to irregularities in any part of the circuit or apparatus.

fsk: Frequency shift keying.

Function: Refers to the action of any key or lever system providing effects other than normal printing, eg line feed, carriage return, etc.

Governor: A device fitted to a motor to enable its rotational speed to be held constant.

Half duplex: A duplex circuit arranged for operation in one direction at a time the receiving end being able to interrupt the sending end when necessary.

Letter feed: That function which causes the printing mechanism to feed forward after each letter is printed.

Letter shift: That function which restores the mechanism from figures to letter characters.

Lever: A straight bar having one point fixed, which is known as the fulcrum or pivot point, around which the bar may turn, a second point connected to the load to be acted upon, and a third point, which has a force acting upon it.

Line: The portion of a circuit, other than an aerial, external to the apparatus.

Line feed: The function which causes the paper roller, or platen, and paper to turn through a distance of one or two lines of characters (corresponding to single-or double-line feed) thus permitting the text to continue on a new line.

Line telegraphy: The sending or transmission of information from one point to another by means of coded electrica-signals, over telegraph or telephone lines.

Link: A bar or connecting part which unites others.

Limiter: A device in which some characteristic of the output is automatically prevented from exceeding a certain value.

Local record: A system in which the transmitted message is printed out by the receiver of the local teleprinter as well as being transmitted to the line.

Loop: A wire circuit, closed at one end.

Lower case: Numerals, punctuation signs, etc.

Mark: One of the two kinds of elements in the international binary start-stop code. Corresponds to perforating a hole in a paper tape. The opposite condition from space.

Margin: The maximum distortion which, when occurring on any or all of the signals applied to a telegraph receiver, is compatible with correct registration of all the symbols for which the receiver is designed.

Non-polarized relay: A relay, the operation of which depends upon the magnitude of the current flowing in the controlling circuit irrespective of the direction in which the current is flowing.

Open-circuit system: In telegraphy. A system in which there is no current flowing in the circuit unless a signal is being sent.

Pawl: A hinged or pivotted lever which may be allowed to engage with the teeth of a ratchet, and allow the movement of the ratchet to be transferred to other parts.

Perforator: An instrument which produces a perforated tape from the action of operating a keyboard.

Perforated tape: A tape in which the code characters are printed by a series of vertical lines of clean-cut holes, a hole being cut for each mark element, but no holes are cut for space elements.

Polarised relay: A relay, the operation of which depends upon the direction as well as the magnitude of the current in the controlling circuit.

Positive drive clutch: A type of clutch which engages immediately and which cannot slip.

Ratchet: A wheel or spindle on which are cut suitable shaped teeth which: (*a*) allows the spindle to drive in one direction only; (*b*) allows the spindle to be driven in one direction only.

Receiver: That part of the teleprinter which receives and prints the message.

Relay: A device, by means of which the input power is used to control a local source of energy.

Reperforator: An instrument which converts incoming electrical impulses of the five-unit code into equivalent perforations of a paper tape.

Side: Each of the independent unidirectional simplex systems of a two-wire simplex, including all apparatus and transmission paths. The two sides are referred to as the "Send" and "Receive" sides, according to the direction of transmission at the particular station.

Simplex: The general term applied to methods of telegraph working by which only one message can be transmitted on a single circuit at any one time.

Single-current system: A telegraph system in which signals are transmitted by means of unidirectional currents.

Space: One of the two kinds of elements in the international binary start-stop code. Corresponds to not punching a hole in a paper tape. The opposite condition from mark.

Start-stop system—Arythmic system: A system in which each group of signal elements corresponding to a letter or character to be transmitted is preceded by a start signal which serves to prepare the receiving mechanism for the reception and registration of a character, and is followed by a stop signal which serves to bring the receiving mechanism to rest in preparation for the reception of the next character.

System: The general term applied to a method of working over a communication path.

tdms: Telegraph distortion measuring set. An equipment for carrying out distortion and margin tests on various telegraph units.

Telegraphy: That branch of communication in which intelligence is conveyed by a code of signals.

Telegraph distortion: In telegraph systems in which the signals at their origin are characterized by modulation at specific instants, the degree of distortion of the modulations when reproduced at the receiver is the ratio of the difference in delay of reproduction of the instants to the duration of the shortest modulation interval applicable to the particular system under consideration.

Telegraph crosstalk: The interference in one telegraph channel resulting from another telegraph channel or channels.

Telegraph regenerative repeater: A telegraph repeater which receives distorted telegraph signals, and re-transmits signals essentially free from distortion.

Telegraph repeater: An arrangement of apparatus and circuits for receiving telegraph signals, and re-transmitting corresponding signals.

Teleprinter: A self-contained telegraph instrument with a type keyboard for transmission, and a printing mechanism for reception.

Transmitter: That part of the teleprinter which transmits signals under the control of the keyboard.

Trip lever: A lever which trips or releases suddenly after storing energy in a spring, the spring then operating other mechanisms.

Trunion: A flexible link which, in conjunction with a cross-head, converts angular motion into parallel motion.

tu: Terminal unit. An instrument which provides an interface between a radio receiver, line, etc and a telegraph machine, providing the necessary electrical impulses to operate the machine.

Two-way simplex system: In telegraphy, a system consisting of two independent simplex systems, each arranged for operation in one direction only, one for transmission in one direction and the other for transmission in the reverse direction.

Typed chadless tape: Chadless tape with the message printed on the tape as well as the chadless perforation.

Upper case: In teleprinter working, the letters of the alphabet.

Voice-frequency telegraphy: A telegraph system in which transmission is effected by an alternating current, or currents, having a frequency or frequencies within the audio range.

Who are you? or answer-back: A device which when released by the receiving mechanism in response to an appropriate signal from the distant end controls the transmitter and causes it to send back automatically a predetermined word, code or phrase.

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APPENDIX

Teletype equipment gear speed identification table

MODEL 15 AND 19 LEFT-HAND PINION (DRIVE) GEAR

Gear	Teeth	Telegraph speed	Motor speed
74912	7T	60	1,800
74913	30T	60	1,800
74505	7T	60	2,100
74151	35T	60	2,100
84018	7T	60	1,500
84019	25T	60	1,500
91286	7T	75	1,800
91287	24T	75	1,800
84105	8T	75	2,100
114460	?T	66	1,800
114461	?T	66	1,800

MODEL 14 REPERFORATOR, RIGHT-HAND PINION

Gear	Teeth	Telegraph speed	Motor speed
78510	7T	60	1,800
78509	30T	60	1,800
71974	7T	60	2,100
73106	35T	60	2,100
84064	7T	60	1,500
84065	25T	60	1,500
94267	7T	75	1,800
88945	24T	75	1,800
7082	8T	75	2,100
6991	32T	75	2,100
110876	16T	100	1,800
110877	42T	100	1,800
110881	14T	100	2,100
110882	43T	100	2,100

MODEL 28 PRINTER, 60T NYLON MAINSHAFT GEAR; 151129 48T STEEL INTERMEDIATE GEAR

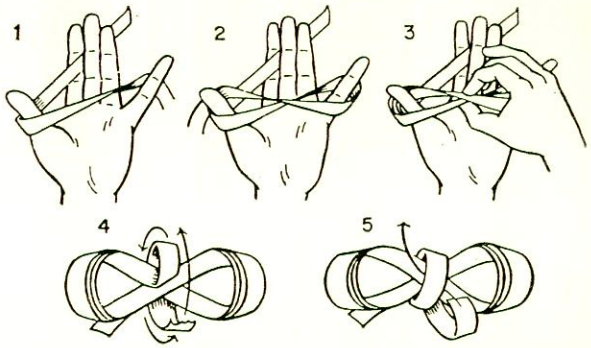
Gear	Teeth	Telegraph speed	
151130	96T	60	
151131	96T	60	
148085	14T	60	ASR
159278	14T	60	Nylon set
159279	96T	60	Nylon set
151132	17T	75	Fibre set
151133	93T	75	Fibre set
159281	17T	75	Nylon set
159282	93T	75	Nylon set
158083	17T	75	ASR
151134	20T	100	Fibre set
151135	84T	100	Fibre set
158181	20T	100	ASR
159284	20T	100	Nylon set
159285	84T	100	Nylon set

(TT25 is receiving TD, turns at receiving speed; TT26 dual-channel transmitter TD, no clutch.)
Motors: 14, 15, 19 generally 1,800 synchonous or 2,100 governor controlled (set by "87·6 vibrations/s" fork).
NOTE: 1,500 and 1,800 governor controlled and dual-speed governor controlled may occasionaly be found.
28: both synchronous and governor controlled are 3,600 rev/min governor controlled set by 120 vibrations/s fork.

MODEL 14 TD, LEFT-HAND PINION

Gear	Teeth	Telegraph speed	Motor speed	
80164	6T	40	1,800	
80163	45T	40	1,800	
87371	6T	50	1,800	
135062	34T	50	1,800	metal clutch
123717	8T	50	2,100	
135069	53T	50	2,100	metal clutch
80166	9T	60	1,800	
80165	44T	60	1,800	
135036	44T	60	1,800	metal cluth
87222	44T	60	1,800	TT26 no clutch
77034	7T	60	2,100	
77036	40T	60	2,100	
135068	40T	60	2,100	metal clutch
84357	40T	60	2,100	TT26 no clutch
91131	13T	60	1,500	
91132	53T	60	1,500	
135067	53T	60	1,500	metal clutch
136582	13T	65	1,800	
136583	60T	65	1,800	metal clutch
116767	11T	66	1,800	
135065	50T	66	1,800	metal clutch
123711	10T	66	2,100	
135065	53T	66	2,100	metal clutch
91285	12T	75	1,800	
136525	47T	75	1,800	
136525	47T	75	1,800	metal clutch
91283	7T	75	2,100	
135064	32T	75	2,100	metal clutch
110883	12T	100	1,800	
135035	36T	100	1,800	metal clutch
77025	10T	100	2,100	
135061	35T	100	2,100	metal clutch
104579	7T	60	1,800	TT25 rcvg TD
104580	30T	60	1,800	TT25 rvcg TD
104659	9T	60	2,100	TT25 rcvg TD
104558	45T	60	2,100	TT25 rcvg TD

Storing Tapes



An easy way of storing transmission tapes. Just follow the steps shown in the diagram.

88 mH TOROID RESONANCE INFORMATION

Table to find capacitance to resonate an 88 mH toroid in 5Hz steps.

f/Hz	Capacity/μF
1,000	0·287844
1,005	0·284987
1,010	0·282172
1·015	0·279399
1,020	0·276666
1,025	0·273974
1,030	0·271320
1,035	0·268705
1,040	0·266128
1,045	0·263587
1,050	0·261083
1,055	0·258614
1,060	0·256180
1,065	0·253780
1,070	0·251414
1,075	0·249081
1,080	0·246780
1,085	0·244510
1,090	0·242272
1,095	0·240065
1,100	0·237887
1,105	0·235739
1,110	0·233620
1,115	0·231530
1,120	0·229467
1,125	0·227432
1,130	0·225424
1,135	0·223442
1,140	0·221486
1,145	0·219556
1,150	0·217651
1,155	0·215771
1,160	0·213915
1,165	0·212082
1,170	0·210274
1,175	0·208488
1,180	0·206725
1,185	0·204984
1,190	0·203265
1,195	0·201568
1,200	0·199891
1,205	0·198236
1,210	0·196601
1,215	0·194986
1,220	0·193391
1,225	0·191816
1,230	0·190259
1,235	0·188722
1,240	0·187203
1,245	0·185702
1,250	0·184220
1,255	0·182755
1,260	0·181307
1,265	0·179877
1,270	0·178463
1,275	0·177066
1,280	0·175686
1,285	0·174321
1,290	0·172972
1,295	0·171639
1,300	0·170322
1,305	0·169019
1,310	0·167731
1,315	0·166458
1,320	0·165199
1,325	0·163955
1,330	0·162724
1,335	0·161508
1,340	0·160305
1,345	0·159115
1,350	0·157939
1,355	0·156775
1,360	0·155625
1,365	0·154487
1,370	0·153361
1,375	0·152248
1,380	0·151146
1,385	0·150057
1,390	0·148979
1,395	0·147913
1,400	0·146859
1,405	0·145815
1,410	0·144783
1,415	0·143762
1,420	0·142751
1,425	0·141751
1,430	0·140762

f/Hz	Capacity/μF
1,435	0·139782
1,440	0·138813
1,445	0·137854
1,450	0·136905
1,455	0·135966
1,460	0·135036
1,465	0·134116
1,470	0·133205
1,475	0·132304
1,480	0·131411
1,485	0·130528
1,490	0·129653
1,495	0·128787
1,500	0·127930
1,505	0·127082
1,510	0·126241
1,515	0·125410
1,520	0·124586
1,525	0·123770
1,530	0·122963
1,535	0·122163
1,540	0·121371
1,545	0·120587
1,550	0·119810
1,555	0·119041
1,560	0·118279
1,565	0·117524
1,570	0·116777
1,575	0·116036
1,580	0·115303
1,585	0·114577
1,590	0·113857
1,595	0·113145
1,600	0·112439
1,605	0·111739
1,610	0·111046
1,615	0·110360
1,620	0·109680
1,625	0·109006
1,630	0·108338
1,635	0·107676
1,640	0·107021
1,645	0·106371
1,650	0·105727
1,655	0·105090
1,660	0·104457
1,665	0·103831
1,670	0·103210
1,675	0·102595
1,680	0·101985
1,685	0·101381
1,690	0·100782
1,695	0·100188
1,700	0·099600
1,705	0·099106
1,710	0·098438
1,715	0·097865
1,720	0·097297
1,725	0·096734
1,730	0·096175
1,735	0·095622
1,740	0·095073
1,745	0·094329
1,750	0·093989
1,755	0·093455
1,760	0·092924
1,765	0·092399
1,770	0·091877
1,775	0·091361
1,780	0·090848
1,785	0·090340
1,790	0·089836
1,795	0·089336
1,800	0·088840
1,805	0·088349
1,810	0·087861
1,815	0·087378
1,820	0·086899
1,825	0·086423
1,830	0·085951
1,835	0·085484
1,840	0·085020
1,845	0·084559
1,850	0·084103
1,855	0·083650
1,860	0·083201
1,865	0·082756

f/Hz	Capacity/μF
1,870	0·082314
1,875	0·081875
1,880	0·081440
1,885	0·081009
1,890	0·080581
1,895	0·080156
1,900	0·079735
1,905	0·079317
1,910	0·078902
1,915	0·078491
1,920	0·078082
1,925	0·077577
1,930	0·077275
1,935	0·076876
1,940	0·076481
1,945	0·076088
1,950	0·075698
1,955	0·075311
1,960	0·074928
1,965	0·074547
1,970	0·074169
1,975	0·073794
1,980	0·073422
1,985	0·073052
1,990	0·072686
1,995	0·072322
2,000	0·071961
2,005	0·071602
2,010	0·071246
2,015	0·070893
2,020	0·070543
2,025	0·070195
2,030	0·069849
2,035	0·069507
2,040	0·069166
2,045	0·068828
2,050	0·068493
2,055	0·068160
2,060	0·067830
2,065	0·067502
2,070	0·067176
1,075	0·066853
2,080	0·066532
2·085	0·066213
2,090	0·065896
2·095	0·065582
2,100	0·065270
2,105	0·064961
2,110	0·064653
2,115	0·064348
2,120	0·064045
2,125	0·063744
2,130	0·063445
2,135	0·063148
2,140	0·062853
2,145	0·062560
2,150	0·062270
2,155	0·061981
2,160	0·061695
2,165	0·061410
2,170	0·061127
2,175	0·060846
2,180	0·060568
2,185	0·060291
2,190	0·060016
2,195	0·059743
2,200	0·059471
2,205	0·059202
2,210	0·058934
2,215	0·058669
2,220	0·058405
2,225	0·058143
2,230	0·057882
2,235	0·057623
2,240	0·057366
2,245	0·057111
2,250	0·056858
2,255	0·056606
2,260	0·056356
2,265	0·056107
2,270	0·055860
2,275	0·055615
2,280	0·055371
2,285	0·055129
2,290	0·054889
2,295	0·054650
2,300	0·054412

f/Hz	Capacity/μF
2,305	0·054177
2,310	0·053942
2,315	0·053710
2,320	0·053478
2,325	0·053249
2,330	0·053020
2,335	0·052793
2,340	0·052568
2,345	0·052344
2,350	0·052122
2,355	0·051901
2,360	0·051681
2,365	0·051463
2,370	0·051246
2,375	0·051030
2,380	0·050816
2,385	0·050603
2,390	0·050392
2,395	0·050181
2,400	0·049972
2,405	0·049765
2,410	0·049559
2,415	0·049354
2,420	0·049150
2,425	0·048947
2,430	0·048746
2,435	0·048546
2,440	0·048347
2,445	0·048150
2,450	0·047954
2,455	0·047758
2,460	0·047564
2,465	0·047372
2,470	0·047180
2,475	0·046990
2,480	0·046800
2,485	0·046612
2,490	0·046425
2,495	0·046239
2,500	0·046055
2,505	0·045871
2,510	0·045688
2,515	0·045507
2,520	0·045326
2,525	0·045147
2,530	0·044969
2,535	0·044792
2,540	0·044615
2,545	0·044440
2,550	0·044266
2,555	0·044093
2,560	0·043921
2,565	0·043750
2,570	0·043580
2,575	0·043411
2,580	0·043243
2,585	0·043076
2,590	0·042909
2,595	0·042744
2,600	0·042580
2,605	0·042417
2,610	0·042254
2,615	0·042093
2,620	0·041932
2,625	0·041773
2,630	0·041614
2,635	0·041456
2,640	0·041299
2,645	0·041134
2,650	0·040988
2,655	0·040834
2,660	0·040681
2,665	0·040528
2,670	0·040377
2,675	0·040226
2,680	0·040076
2,685	0·039927
2,690	0·039778
2,695	0·039631
2,700	0·039484
2,705	0·039338
2,710	0·039193
2,715	0·039049
2,720	0·038906
2,725	0·038763
2,730	0·038621
2,735	0·038480

83 mH TOROID RESONANCE INFORMATION—*continued*

f/Hz	Capacity/μF	f/Hz	Capacity/μF	f/Hz	Capacity/μF	f/Hz	Capacity/μF
2,740	0·038200	2,810	0·036453	2,875	0·034824	2,940	0·033301
2,745	0·038340	2,815	0·036324	2,880	0·034703	2,945	0·033188
2,750	0·038062	2,820	0·036195	2,885	0·034583	2,950	0·033076
2,755	0·037924	2,825	0·036067	2,890	0·034463	2,955	0·032964
2,760	0·037786	2,830	0·035940	2,895	0·034344	2,960	0·032852
2,765	0·037650	2,835	0·035813	2,900	0·034226	2,965	0·032742
2,770	0·037514	2,840	0·035687	2,905	0·034108	2,970	0·032632
2,775	0·037379	2,845	0·035562	2,910	0·033991	2,975	0·032522
2,780	0·037245	2,850	0·035437	2,915	0·033875	2,980	0·032413
2,785	0·037111	2,855	0·035313	2,920	0·033759	2,985	0·032304
2,790	0·036978	2,860	0·035190	2,925	0·033643	2,990	0·032196
2,795	0·036846	2,865	0·035067	2,930	0·033529	2,995	0·032089
2,800	0·036714	2,870	0·034945	2,935	0·033414	3,000	0·031982
2,805	0·036584						

Left-hand column shows frequency, right-hand column shows capacitance in μF.

DRILL SIZES FOR PC BOARDS

Listed are five common size drills used for piercing printed circuit boards when mounting the following components:

709C op. amps.	Drill No. 77
¼W resistors	Drill No 70
½W resistors	Drill No 64
1W resistors	Drill No 57
2W resistors	Drill No 55

IMPERIAL/METRIC CONVERSION TABLE

Inches	Millimetres	Inches	Millimetres	Inches	Millimetres
0·001	0·025	0·034	0·864	0·067	1·70
0·002	0·051	0·035	0·889	0·068	1·73
0·003	0·076	0·036	0·914	0·069	1·75
0·004	0·102	0·037	0·940	0·070	1·78
0·005	0·127	0·038	0·965	0·071	1·80
0·006	0·152	0·039	0·991	0·072	1·83
0·007	0·178	0·040	1·02	0·073	1·85
0·008	0·203	0·041	1·04	0·074	1·88
0·009	0·229	0·042	1·07	0·075	1·90
0·010	0·254	0·043	1·09	0·076	1·93
0·011	0·279	0·044	1·12	0·077	1·95
0·012	0·305	0·045	1·14	0·078	1·98
0·013	0·330	0·046	1·17	0·079	2·00
0·014	0·356	0·047	1·19	0·080	2·03
0·015	0·381	0·048	1·22	0·081	2·06
0·016	0·406	0·049	1·24	0·082	2·08
0·017	0·432	0·050	1·27	0·083	2·11
0·018	0·457	0·051	1·30	0·084	2·13
0·019	0·483	0·052	1·32	0·085	2·16
0·020	0·508	0·053	1·35	0·086	2·18
0·021	0·533	0·054	1·37	0·087	2·21
0·022	0·559	0·055	1·40	0·088	2·23
0·023	0·584	0·056	1·42	0·089	2·26
0·024	0·610	0·057	1·45	0·090	2·29
0·025	0·635	0·058	1·47	0·091	2·31
0·026	0·660	0·059	1·50	0·092	2·34
0·027	0·686	0·060	1·52	0·093	2·36
0·028	0·711	0·061	1·55	0·094	2·39
0·029	0·737	0·062	1·58	0·095	2·41
0·030	0·762	0·063	1·60	0·096	2·44
0·031	0·787	0·064	1·63	0·097	2·46
0·032	0·813	0·065	1·65	0·098	2·49
0·033	0·838	0·066	1·68	0·099	2·51

NOTE: 1 mil = 0·001 inches = 0·025 millimetres

Imperial/metric conversion table.

Teleprinter Compatibility

Creed 3X/7B and Teletype 15 compatibility chart.

CREED MODEL 3		CREED MODEL 7		TELETYPE		PERFORATED TAPE				
Lower case	Upper case	Lower case	Upper case	Lower case	Upper case	Code Elements				
						1	2	3	4	5
A	Who are you	A	—	A	—	●	●	○		
B	?	B	?	B	?	●		○		●
C	(	C	:	C	:		●	○	●	●
D	2	D	Who are you	D	$	●		○		●
E	3	E	3	E	3	●		○		
F	1/	F	%	F	!	●		○	●	●
G	3/	G	@	G	&		●	○		●
H	5/	H	£	H	£ or STOP			○	●	
I	8	I	8	I	8		●	○	●	
J	7/	J	BELL	J	'	●	●	○		●
K	9/	K	(	K	(	●	●	○	●	●
L	+	L	)	L	)		●	○		●
M	,	M	.	M	.			○	●	●
N	—	N	,	N	,			○	●	●
O	9	O	9	O	9			○		●
P	Ø	P	Ø	P	Ø		●	○	●	
Q	1	Q	1	Q	1	●	●	○	●	
R	4	R	4	R	4		●	○		●
S	1	S	'	S	BELL	●		○	●	
T	5	T	5	T	5			○		●
U	7	U	7	U	7	●	●	○	●	
V	)	V	=	V	;		●	○	●	●
W	2	W	2	W	2	●	●	○		●
X	£	X	/	X	/	●		○	●	●
Y	6	Y	6	Y	6	●		○	●	
Z	.	Z	+	Z	"	●		○		●
—	=	Carriage Return		Carriage Return				○		
/	/	Line Feed		Line Feed			●	○		
*	*	Letters		Letters		●	●	○	●	●
Figures and Space		Figures		Figures		●	●	○		●
Letters and Space		Space		Space				○	●	
Not Used		Not Used		Not Used				○		

● Represents a "Mark" element. The smaller holes in the perforated tape are the sprocket feed holes.

Appendix 4

CREED MODEL 75 DRIVE GEARS

			Index Letter	Machines fitted with a governed motor				
				Baud speed and colour code				
				45	50	56	74	75
				Green	Yellow	Black	Red	Blue
For machines normally operating at CCITT speeds	machines fitted with a single speed selector unit S4278	Drive shaft	A	4009/26C	4009/26C	4009/26C	4009/26C	4009/26C
		Cam shaft gear	B	4009/161B	4009/161B	4009/161B	4009/161B	4009/161B
		Driven gear	C	4009/93A	4009/94A	4009/199A	4009/222	4009/95A
		Motor pinion	D	GR2199	GR2198	GR2223	GR2228	GR2201
	machines fitted with a gear box selector unit S4279	Drive shaft	A	4019/3C	4019/3C	4019/3C		4019/3C
		Cam shaft gear	B	4009/161B	4009/161B	4009/161B		4009/161B
		Driven gear	C	4019/6A	4019/7A	4019/27		4019/17A
		Motor pinion	D	GR2207	GR2208	GR2261		GR2221

			Index Letter	Machines fitted with a 50 cycles synchronous motor				
				Baud speed and colour code				
				45	50	56	74	75
				Yellow Green	Yellow Red			Yellow Blue
For machines normally operating at CCITT speed	machines fitted with a single speed selector unit S4278	Drive shaft	A	4009/26C	4009/26C			4009/26C
		Cam shaft gear	B	4009/161B	4009/161B			4009/161B
		Driven gear	C	4009/369	4009/251			4009/356
		Motor pinion	D	GR2272	GR2238			GR2270
	machines fitted with a gear box selector unit S4279	Drive shaft	A	4019/3C	4019/3C			4019/3C
		Cam shaft gear	B	4009/161B	4009/161B			4009/161B
		Driven gear	C	4019/37	4019/38			4019/39
		Motor pinion	D	GR2268	GR2269			GR2271

			Index Letter	Machines fitted with a 60 cycles synchronous motor				
				Baud speed and colour code				
				45	50	56	74	75
					Black Orange			Black Blue
	machines fitted	Drive shaft	A		4009/26C			4009/26C
For machines normally operating at CCITT speed	with a single speed selector S4278	Cam shaft gear	B		4009/161B			4009/161B
		Driven gear	C		4009/358			4009/365
		Motor pinion	D		GR2267			GR2273
				Pink	Orange	Brown	White	Violet
For machines normally operating at American speeds	machines fitted with a single speed selector unit S4278	Drive shaft	A	4009/215A	4009/215A	4009/215A	4009/215A	4009/215A
		Cam shaft gear	B	4009/213A	4009/213A	4009/213A	4009/213A	4009/213A
		Driven gear	C	4009/218A	4009/226	4009/224	4009/216A	4009/248
		Motor pinion	D	GR2225A	GR2230	GR2229	GR2224A	GR2237
	machines fitted with a gear box selector unit S4279	Drive shaft	A	4019/35		4019/35	4019/35	
		Cam shaft gear	B	4009/213A		4009/213A	4009/213A	
		driven gear	C	4019/30		4019/32	4019/31	
		Motor pinion	D	GR2262		GR2264	GR2263	

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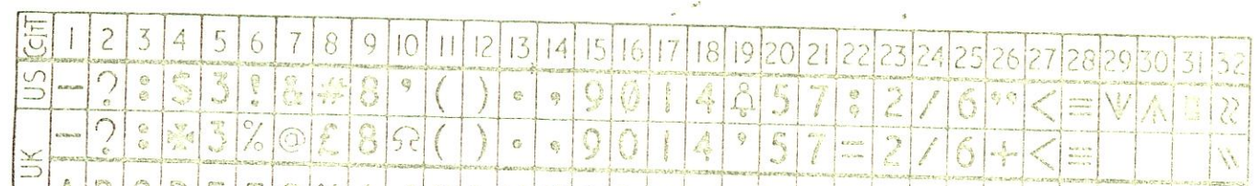
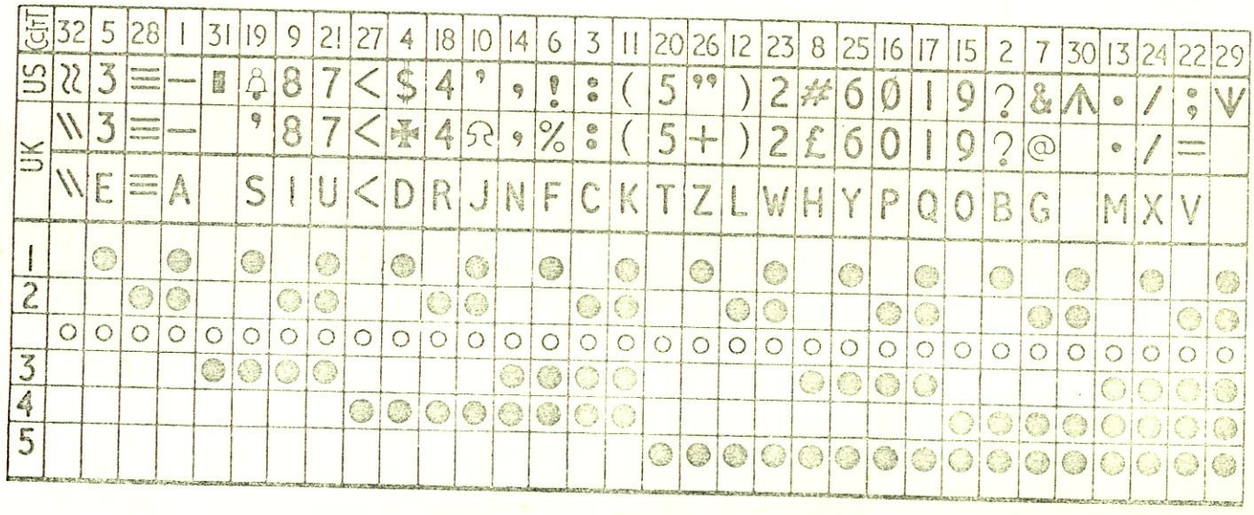


5 Unit Code Key settings in alphabetical order



5 Unit Code Key settings in binary order